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OF
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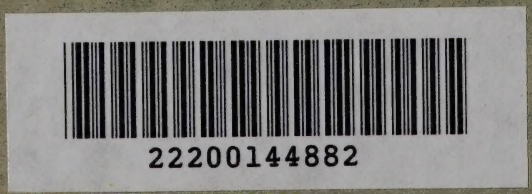
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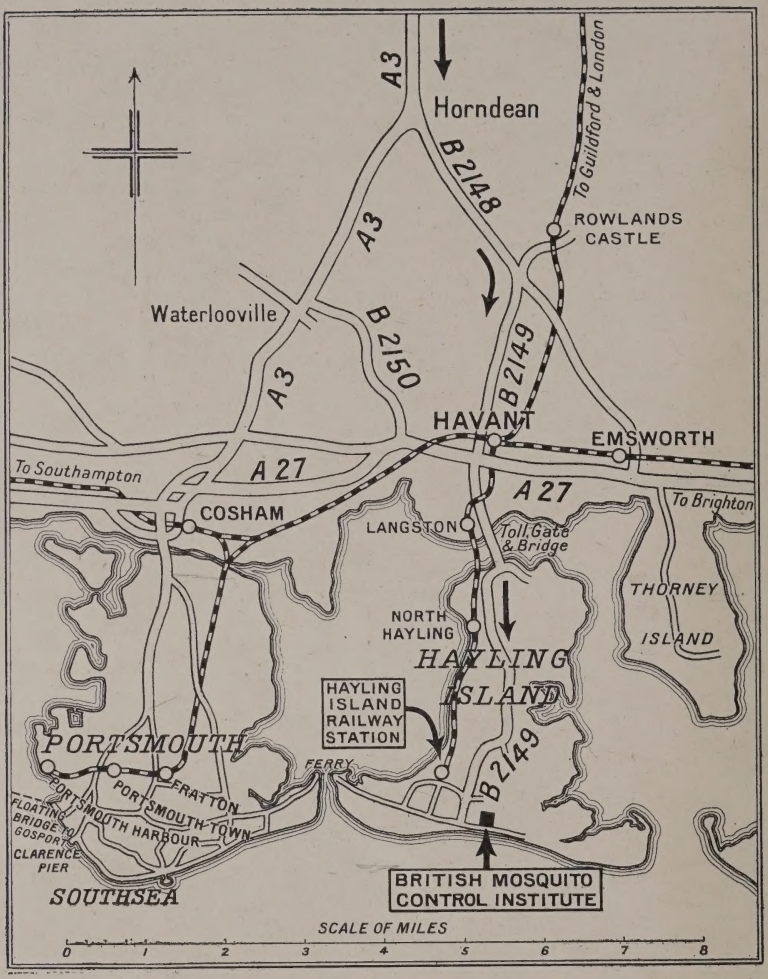

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PRINCIPLES AND PRACTICE
OF
MOSQUITO CONTROL

BEING A HANDBOOK TO THE
BRITISH MOSQUITO CONTROL INSTITUTE

BY

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—

WITH 53 ORIGINAL ILLUSTRATIONS.

—

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PREFACE.

The preparation of this Handbook was undertaken as a descriptive response to numerous enquiries at the British Mosquito Control Institute as to the means of suppressing mosquitoes not only in Great Britain but also in many other parts of the world.

The Institute owes its inception to the success of the work which was initiated in the year 1920 to deal with the intolerable nuisance caused by mosquitoes in Hayling Island.

In the course of this work (which has entirely abolished the long-standing nuisance in question) a large number of new facts relating to the control of mosquitoes have been demonstrated, and a definite system of mosquito control organization has been evolved.

In addition to affording the only opportunity available in this country for the practical study of the working details of a mosquito control scheme in actual and continuous operation, the Institute is equipped for carrying on research, and providing instruction, in all branches of mosquito investigation. It is also able to undertake the inspection of mosquito infested areas and to advise upon possible means of dealing with them.

The Institute is in the position to supply, for educational or research purposes, living or mounted specimens of British mosquitoes in the different stages of their life history, as well as stereoscopic and other photographs, lantern slides, and diagrams, illustrating the characteristics of various species and the methods of controlling them.

Up to the present, the Institute has not (as is generally assumed) received any financial assistance from official bodies or from local authorities, but has had to rely almost exclusively upon voluntary contributions either in the form of donations or of membership subscriptions. It is to be hoped that sufficient funds will be forthcoming from annual subscribers or other sources to enable the Institute to carry on its work efficiently, and possibly to extend its operations in the near future.

Particulars relating to Membership, etc. of the Institute are given on page 22.

JOHN F. MARSHALL.

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THE BRITISH MOSQUITO CONTROL INSTITUTE,

Hayling Island, Hampshire.

(Incorporated February 12th, 1927).

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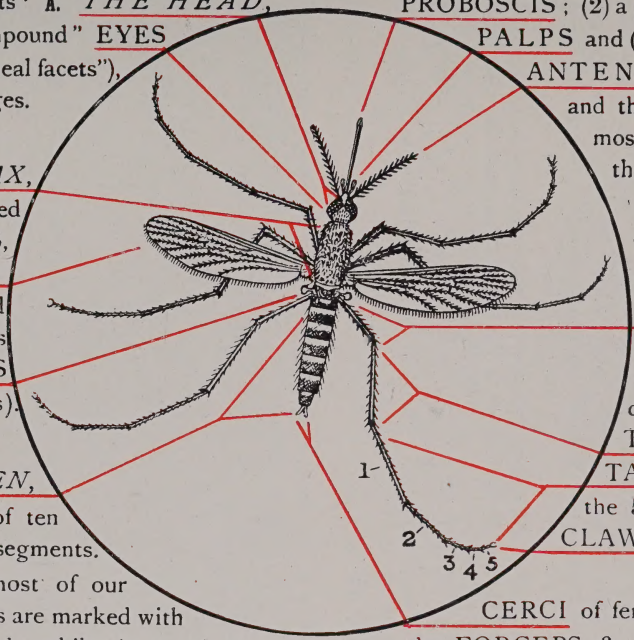
Fig. 1. HOW TO RECOGNISE A MOSQUITO.

The body of a MOSQUITO (which is a "dipterous," or "two-winged" insect), is composed of 3 parts: **A.** *THE HEAD*, which has two "compound" EYES (with numerous "corneal facets"), and certain appendages.

B. *THE THORAX*, to which are attached three pairs of LEGS, a pair of WINGS with scaled veins, and a pair of projections called HALTERES (vestigial hind wings).

C. *THE ABDOMEN*, which is composed of ten (eight only visible) segments. The abdomens of most of our ***Culicine*** mosquitoes are marked with light transverse bands, while those of our ***Anopheline*** mosquitoes are uniformly dark.



The head appendages are (1) a sheathed "bundle" of pointed instruments, called the PROBOSCIS; (2) a pair of MAXILLARY PALPS and (3) a pair of (14-jointed) ANTENNAE. The palps* and the antennae of female mosquitoes are *slender*; those of males, *bushy*.

The conspicuous parts of the LEG are the FEMUR, (connected to the thorax by two short joints, the Trochanter and Coxa); the TIBIA; & the 5-jointed TARSUS. At the tip of the 5th tarsal joint are the CLAWS.

The CERCI of female mosquitoes (and the FORCEPS, &c., of males) project at the extremity of the abdomen.

* The palps of a *female* **Culicine** mosquito (above illustrated) are slender and *short*; those of a *female* **Anopheline** mosquito are slender and *long*.

Facing p. viii

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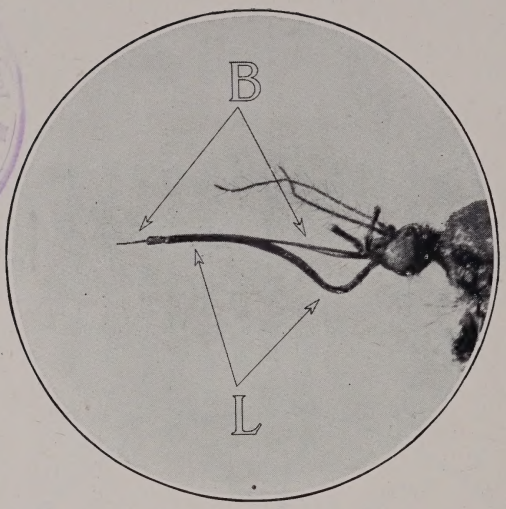

Fig. 2. Head of a female Culicine mosquito, showing the proboscis sheath or *labium* (L) partly drawn back in the act of biting, and the "bundle" (B) of six instruments projecting The bundle (B) comprises (i) two pairs of "lancets," the *maxillae* and the *mandibles*; (ii) the *hypopharynx*; and (iii) the *labrum-epipharynx*. These instruments are respectively employed by the female mosquito for (i) puncturing our skin, (ii) inoculating us with saliva and (iii) sucking our blood.

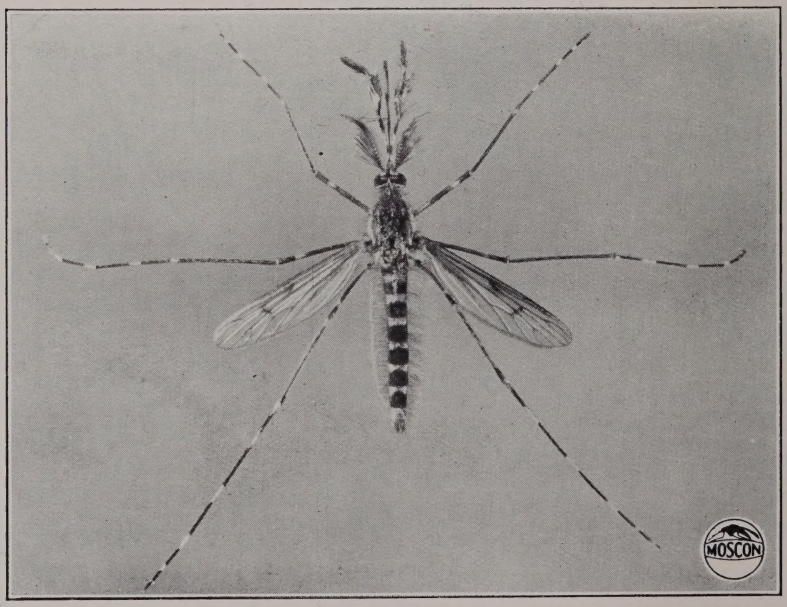

Fig. 3. Male of the Culicine mosquito *Theobaldia annulata* (× 4). Note the **bushy antennae** and the **long tufted palps** (with the proboscis showing between them), two characteristic features of *male* mosquitoes.

I.

GENERAL NOTES CONCERNING MOSQUITOES AND THEIR CONTROL.

A Mosquito is a two-winged insect which is very easily recognised by its long "beak" or "proboscis." This proboscis is actually a sheath concealing (in the case of *female* mosquitoes) a bundle of six pointed instruments designed for puncturing the skin, and sucking the blood, of human beings and other animals. (Fig. 2).

The male mosquito, whose proboscis contains less formidable weapons, is a strict vegetarian and, therefore, does not seek the society of human beings. Hence the mosquitoes which settle on us, preparatory to biting, are invariably *females.*

Mosquitoes are to be met with all over the world, the total number of species at present known being over 1400. They are separable into two great divisions or "tribes," the **Anophelines** and the **Culicines,** something like three-quarters of the mosquitoes of the world belonging to the latter tribe. In Great Britain there are 25 different species of mosquitoes, no fewer than 22 of which are of the **Culicine** kind.

The head of a mosquito is provided not only with a proboscis but also with two pairs of appendages called the *antennae* and the *maxillary palps.* (Fig. 1). The antennae of **males** are *bushy* (Figs. 3 and 48) and those of **females** *slender or "threadlike."* (Figs. 8 and 9). The palps are also quite different in the two sexes, being *long and "tufted"* in **males** (Figs. 3 and 48), and *slender* in **females.** The palps of **female Culicine** mosquitoes are only about *one-fifth the length of the proboscis* (and therefore hardly noticeable), but those of **female Anopheline** mosquitoes are about *as long as the proboscis;* hence female adults of the two tribes are very easily distinguished from one another. (Figs. 7 and 8).

A meal of blood is not indispensable for keeping a mosquito alive, but is probably an essential preliminary to the process of egg-laying. A mosquito lays from 50 to 300 eggs at a time (according to the species), the eggs being in most cases laid separately. In the case of certain species, however, the mosquito lays her eggs and at the same time "sticks them together," thus forming curious conglomerate masses called "egg-rafts."

Mosquito eggs are sometimes laid on water and sometimes on land, according to the different species concerned. Eggs which have been either (1) laid on water or (2) laid on land *and subsequently brought into contact with water owing to*

rainfall or other causes, eventually hatch out into *larvae*, the familiar "wriggly" creatures so frequently observed in stagnant water. A mosquito larva breathes through a pair of orifices, known as *spiracles*, situated on the eighth abdominal segment in the case of **Anopheline** larvae, and at the extremity of a tail-like tube (the "*siphon*") projecting from the eighth abdominal segment, in the case of **Culicine** larvae. These *spiracles* are actually the intake ends of a pair of *tracheae* (breathing organs) which extend as far as the thorax. (Fig. 11). The **Anopheline** larva therefore lies *horizontally*, and the **Culicine** larva *head downwards*, when breathing: the spiracles in each case breaking the surface film.* A mosquito larva is able to take nourishment in two entirely different ways—either by oscillating a pair of curious "mouth brushes" and thus creating a miniature whirlpool (which causes a random collection of floating particles to be attracted and swallowed), or by actually devouring algae, dead leaves, "water fleas" and many other food materials.

Recent investigations as to the food preferences of different species of larvae are expected to lead to important developments in connection with mosquito control work. (Fig. 12).

The larva changes its skin four times during the period of growth, the stages between successive "moults" being known as "instars." After the fourth moult, the larva becomes a *pupa*, a curious bulbous creature with a lobster-like "tail." Contrary to the larva, the pupa rests *tail downwards* in the water, taking in air through a pair of trumpet-like tubes projecting from its thoracic region. The pupa has no mouth and, therefore, neither eats nor drinks. At the end of a few days it splits open and the adult mosquito struggles forth. (Figs. 4 & 6.)

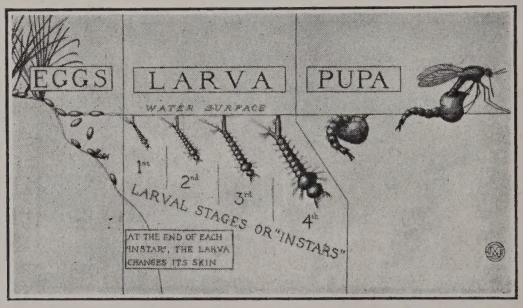

Fig. 4. Stages in the development of a **Culicine** mosquito.

It should be noted that the larval and pupal stages are passed entirely in water, the total period of growth varying

* Mosquito larvae, being heavier than water, have to make swimming movements to reach the surface, from which they are enabled to remain suspended by capillary attraction acting (1) in the case of **Culicine** larvae, upon the edges of five openable flaps at the tip of the "siphon," and (2) in the case of **Anopheline** larvae, upon a double row of branched ("palmate") hairs situated on the dorsal surface of the abdomen. (See Fig. 47, p. 32.)

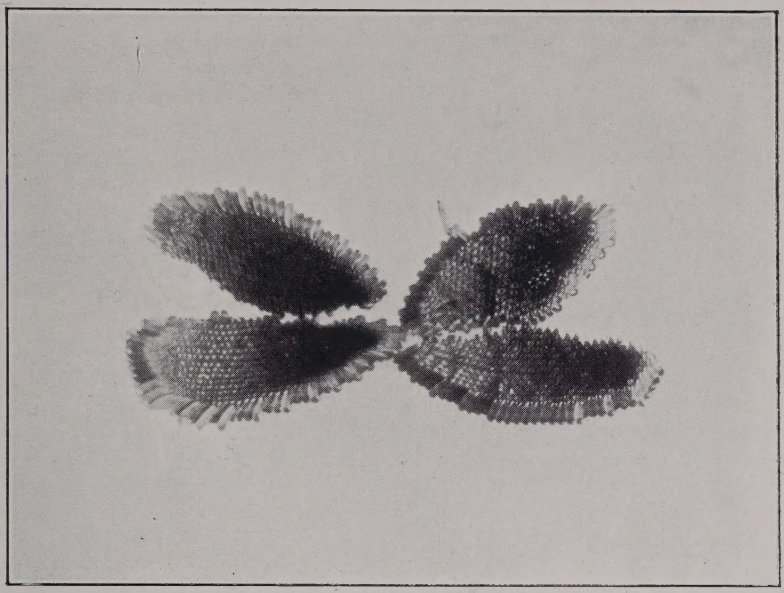

Fig. 5. "Egg rafts" of the domestic mosquito *Culex pipiens* (× 7). The above rafts (collected in the same water butt) are "bundles" of mosquito eggs, 315, 307, 310 and 299 in number. The total number of eggs produced by the *four* mosquitoes concerned was therefore 1,231.

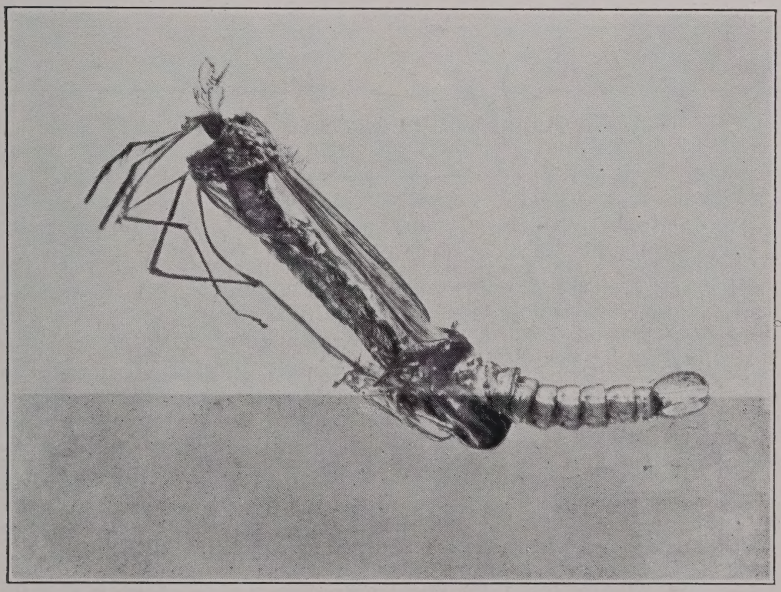

Fig. 6. A male mosquito (*Theobaldia annulata*) emerging from the pupal skin.

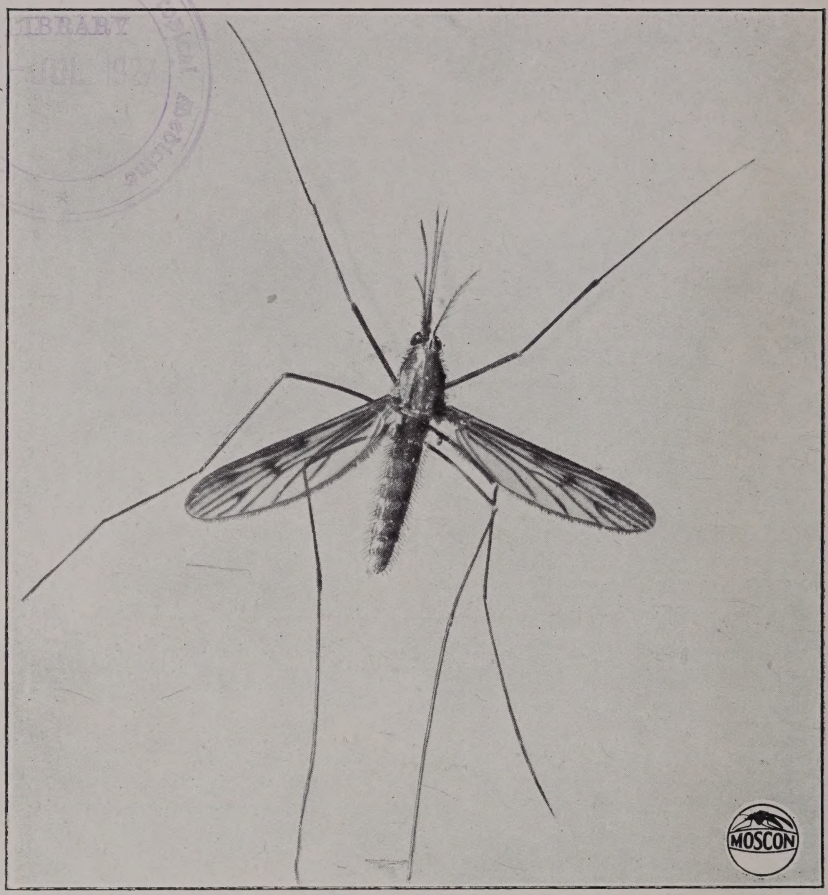

Fig. 7. Female of the **Anopheline** mosquito *Anopheles maculipennis.*

[About 6 times natural size.]

Anopheles maculipennis has "spotted" wings*, the only other English species with this characteristic feature being the Culicine mosquito *Theobaldia annulata.* These two species are, however, very easily differentiated by the fact that the palps of female Anopheline mosquitoes are long (as shown above), and those of female Culicine mosquitoes very short. (Figs. 1, 8 & 9). Moreover, the legs of *Anopheles maculipennis* are uniformly dark, whereas those of *Theobaldia annulata* are conspicuously ringed. (Fig. 9.)

Anopheles maculipennis is a "malaria carrier"; that is to say, the females are able, after biting a person suffering from malaria, to inoculate with the disease other persons whom they may subsequently attack. As this mosquito is quite common all over England, it is fortunate that the conditions necessary for its infection in the first instance are now of rare occurrence in this country.

Females of this species remain alive throughout the winter months, sheltering chiefly in stables and farm buildings; but they are also not infrequently found in the cellars, attics, &c., of dwelling houses, in company with females of the Culicine species, *Culex pipiens* and *Theobaldia annulata,* the only other English mosquitoes which hibernate. (See p. 5.)

There are two other Anopheline mosquitoes in this country, namely *Anopheles bifurcatus* and *Anopheles plumbeus,* which closely resemble one another. They are easily distinguished from *Anopheles maculipennis* by the absence of wing spots, and from all Culicine mosquitoes by the long (female) palps. Both these species pass the winter in the larval stage. *Anopheles plumbeus* breeds almost exclusively in rain-filled cavities in trees.

* See Appendix A.

from three weeks to several months according to biological, climatic and various other influences: *hence mosquitoes are only produced in districts where water is permitted to stagnate for long intervals of time.**

Although the world-wide importance of mosquitoes in relation to human life is now universally recognised, it was only within the last quarter of the last century that their culpability was first suspected and subsequently demonstrated. During the said period, however, the researches of Manson, Finlay, Ross, James and other investigators conclusively proved that the diseases of *filariasis*, *yellow fever*, *malaria and dengue fever* are transmitted from man to man by the bites of mosquitoes belonging to certain species or groups.

All the mosquitoes which are capable of transmitting malaria from man to man belong to the **Anopheline** tribe. Fig. 7 illustrates a female of the species *Anopheles maculipennis*, showing the long female palps characteristic of the **Anopheline** tribe. This mosquito, which is the chief malaria carrier of Europe, is quite common all over England: but the conditions necessary for its infection in the first instance are of rare occurrence in this country at the present time.

It is a great mistake, however, to suppose that English **Anopheline** mosquitoes—which *do not happen* to convey malaria—and English **Culicine** mosquitoes, which *cannot* do so, are therefore to be regarded as harmless insects. On the contrary, their bites are frequently followed by blood-poisoning and other serious consequences. There are many localities in England (some of them even in the near neighbourhood of London) where mosquitoes create an almost intolerable nuisance throughout every summer and autumn.

We see, therefore, that the unpopularity of mosquitoes arises partly from (i) the power possessed **by certain groups only of conveying definite diseases from man to man,** and partly from (ii) their power of causing **general annoyance** by reason of the irritation and the various unpleasant consequences due to their bites.

Although, as generally known, extensive schemes for "controlling" **disease-conveying** mosquitoes are now being continuously (and most successfully) operated in various parts of the world, the desirability of suppressing mosquitoes which cause **general annoyance** is at present but little realized, except in certain coastal districts of the United States. Prior to the year 1920, when the Hayling Mosquito Control came into existence, no attempt whatever had been made in Great Britain to deal with the mosquito from the purely "nuisance" point of view. At that time, indeed, detailed

* This statement is not universally true. The larvae of many **Anopheline** species habitually develop in *slowly-running* water; "anchoring" themselves to the surface vegetation by means of certain "hook-ended" hairs carried on the ninth abdominal segment. See Fig. 47, p. 32. The existence of these hooks was first pointed out (by Dr. W. A. Lamborn) in 1920.

information applicable to the question of controlling mosquitoes in this country was practically unobtainable; references to the subject in scientific literature almost invariably related to anti-mosquito campaigns which were being carried on in foreign parts, where not only the habits of the mosquitoes but also the climatic, labour, legislative and other local conditions were so totally different from our own, that such information was of little practical value as regards mosquito control in England.

Experience has shown that the only effective means of preventing mosquitoes from breeding is to attack them in the larval stage, either by destroying the larvae or by abolishing the stagnating water which is essential for larval existence. In the first case, the larvae may either be suffocated by covering the surface with a film of oil, or poisoned by mixing substances called "larvicides" with the infested water. In the second case, various engineering methods are made use of to prevent the stagnation of the water.

The methods of the second group are of course much the more satisfactory, because they effect a permanent cure—whereas all schemes of larva destruction have to be repeated periodically. Such schemes are, however, of great value on many occasions, especially in view of the fact that they are applicable literally at a moment's notice. In mosquito control work it is a very common experience to find a collection of stagnant water infested with larvae which, owing to the advanced stage of their growth, are destined to hatch out into adult mosquitoes long before the engineering work of taking levels and constructing drainage channels can be carried out. In a case such as this, oiling or larviciding will render the water untenantable to the larvae until drainage operations are completed.

With all these alternative remedies available, the mosquito problem appears to present very little difficulty. All that seems to be necessary is to oil, poison or drain away the stagnant water of the neighbourhood, and thus banish the mosquitoes permanently from the district. Unfortunately, however, this popular view of the question ignores a number of serious (and sometimes insurmountable) difficulties with which the "mosquito-controller" is compelled to deal.

To commence with, there are (as already stated) no fewer than 25 different species of mosquitoes in this country —and these species differ greatly from one another in many respects, especially as regards their hatching-out periods and the surrounding conditions in which they prefer to exist.

Hence certain kinds of mosquito larvae are found in water butts, others in stagnant ditches, others in badly drained stables, others in woodland pools, others in stagnating sea water, and so on. In organising a mosquito control campaign it is first of all necessary to discover which particular

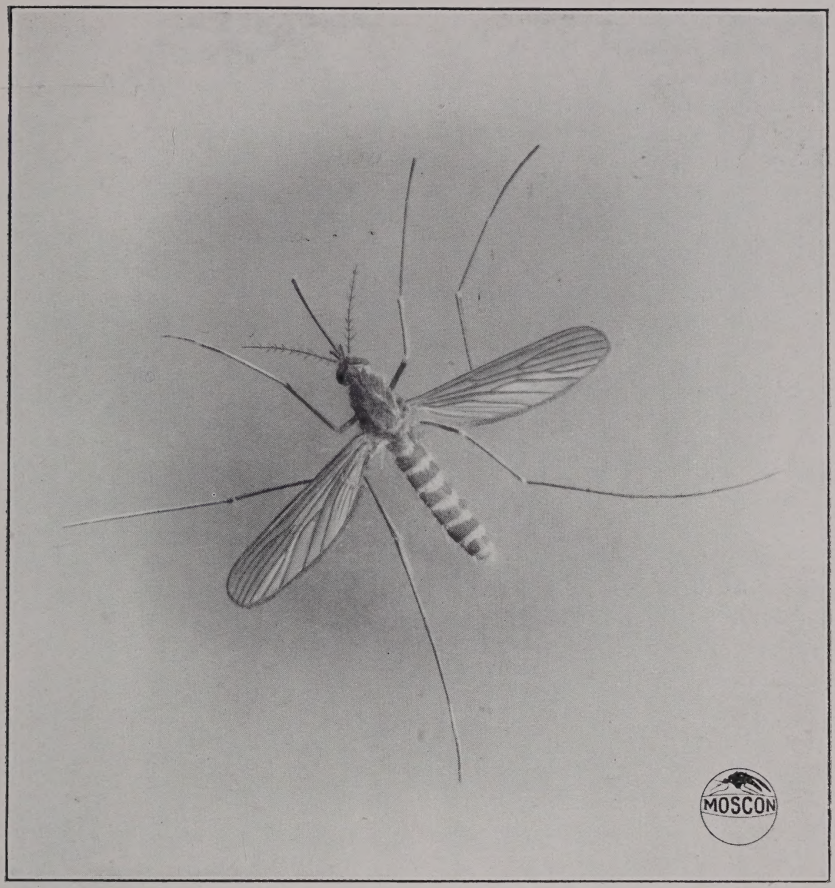

Fig. 8. Female of the **Culicine** mosquito *Culex pipiens.*

[About 6 times natural size.]

Culex pipiens is probably the best known British mosquito, owing to the fact that the females lay their eggs chiefly (though by no means exclusively) in water-butts, garden tanks and suchlike water receptacles in the near neighbourhood of dwelling houses. The eggs of *Culex pipiens* are laid in conglomerate masses or "rafts" (Fig. 5), each raft being composed of about 300 eggs. *Culex pipiens* is one of our (three) "domestic" mosquitoes, female adults of this species invading dwelling houses (often in enormous numbers) at the approach of winter, and subsequently "hibernating" in cellars, attics, dark cupboards, &c., until the arrival of spring. Every householder should therefore be on the look out for hibernating mosquitoes (in his cellars and attics) throughout the winter, and for their larvae (in garden tanks, &c.) throughout the summer and autumn.

Hibernating mosquitoes are easily killed by spraying the walls and ceilings of their lairs with some suitable insecticide solution ; while larvae found in water receptacles may be destroyed either (a) by pouring away the water on the ground, or (b) by covering its surface with a film of paraffin. (Since water and paraffin do not mix, the former can be drawn off unchanged, when required, by means of a siphon or low-level tap).

The biting propensities of *Culex pipiens* appear to depend upon a number of biological, climatic and (even) topographical conditions, the influence of these various factors being at present very imperfectly understood.

Culex pipiens is easily distinguished from all other English mosquitoes by an abnormality in the "venation" of the wings. (See Appendix A.)

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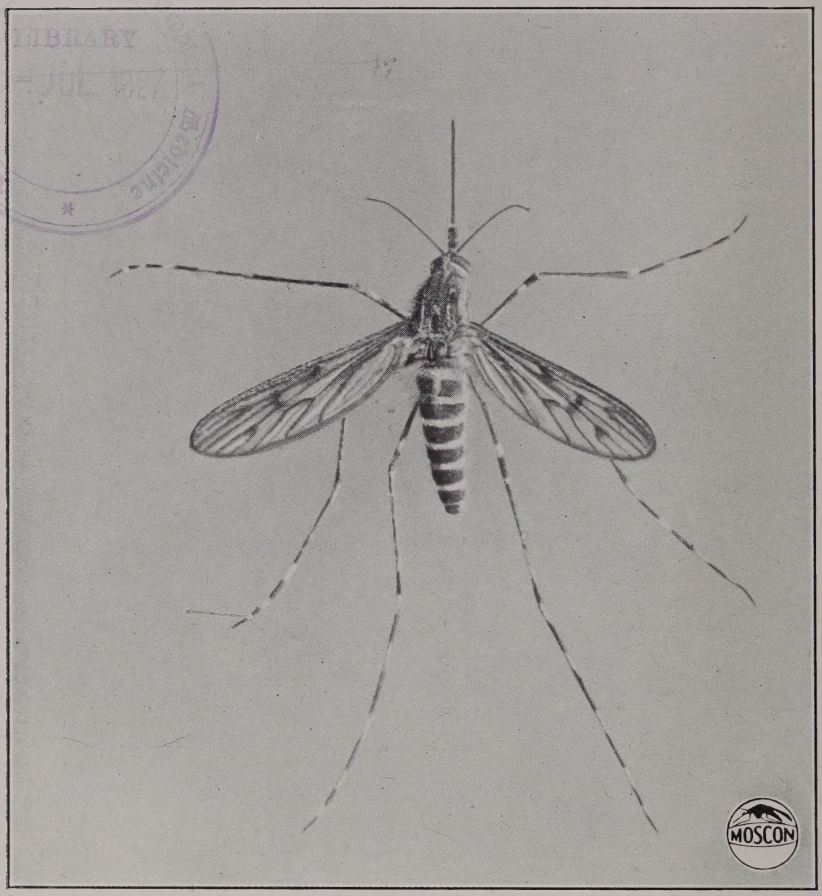

Fig. 9. Female of the **Culicine** mosquito *Theobaldia annulata.*

[About 4½ times natural size.]

Theobaldia annulata, one of our most common British species, is the largest mosquito in Europe. Being the only English mosquito which has "spotted" wings* *as well as* "ringed" legs, it is very easily recognised. Another of its characteristic features is a prominent white *longitudinal* stripe between the 1st and 2nd transverse "bands" of the abdomen. The wing venation is also distinctive.*

The females of *Theobaldia annulata* lay their eggs in "rafts" resembling those of *Culex pipiens* (Fig. 5), but composed of a smaller number of eggs; the average number in a *Theobaldia* raft being about 180. The larvae are generally found in very foul water, especially in that which is contaminated by sewage; but they are also common in water butts and garden tanks during the autumn, in company with the larvae of *Culex pipiens.*

Theobaldia annulata is often referred to as the "large domestic mosquito," because the females hibernate in the cellars, attics, &c., of dwelling houses (together with females of *Culex pipiens)*, and often cause considerable annoyance during the winter months, especially in steam-heated residences. Owing possibly to the insanitary conditions under which mosquitoes of this species generally breed, their bites frequently lead to unpleasant, and even serious, results.

* See Appendix A.

species are prevalent in the district, and then to estimate their relative importance as nuisance producers—so that those which are causing the greatest annoyance shall be the primary objects of attack. The obvious way of gaining this information is to capture and identify large numbers of the local mosquitoes: and this is fortunately a fairly easy matter, since the commoner English species are easily distinguished from one another. (See Figs. 3, 7, 8, 9, 13, &c.). It should be noted that many harmless two-winged insects are frequently mistaken for mosquitoes, but are very easily distinguished from them by the absence of a conspicuous proboscis.

Another very simple method of recognising a mosquito is to examine the wings under a low power magnifying lens. The "wing veins" of all the members of any particular family of insects (such as the mosquitoes) are arranged in some special "pattern" typical of that (and of no other) family. (See Appendix A, page 33).

The British mosquitoes are roughly divisible into three groups, namely:—

(1). The **Domestic** mosquitoes, the females of which live in close association with human beings or domestic animals throughout the winter months.

(2). The **Rural** mosquitoes, comprising various sub-groups of mosquitoes which breed in *woodland pools*, *non-salt swamps*, *rain-filled cavities in trees*, &c.

(3). The **Salt Marsh** or **Coastal** mosquitoes, which breed partly or wholly in stagnant *salt*, *or partly salt*, water.

The **Domestic** group consists of *Culex pipiens* (Fig. 8), *Theobaldia annulata* (Fig. 9), and *Anopheles maculipennis* (Fig. 7). The females of each of these species live through the winter—*Culex pipiens* and *Theobaldia annulata* "hibernating" chiefly in the cellars of dwelling houses, and *Anopheles maculipennis* largely in cowsheds and pigsties. The presence of hibernating mosquitoes in a dwelling house is extremely undesirable, since they are apt to wander at night-time and bite the sleeping occupants. At the approach of winter, therefore, all householders (especially those who reside in steam-heated houses) should examine cellars, attics and other dark recesses, so that any hibernating mosquitoes found may be destroyed by fumigation or spraying.

In the case of mosquitoes belonging to the **Rural** and **Salt Marsh** groups, both the males and females die off before winter: the winter months being passed in either the **egg** or **larval** stage.

Owing to the persistence with which (female) mosquitoes seek the society of human beings, they are very easily captured. It is only necessary to wait until a mosquito "settles" on a wall (or on its prospective victim) and then slip over it a small glass tube containing some lethal substance such as potassium cyanide, chloroform or petrol. A simple way of preparing a tube for this purpose is to fix a plug of cotton wool moistened with petrol into the closed end, by means of a tightly fitting disc of cardboard. The tube should of course be kept corked except when actually in use.

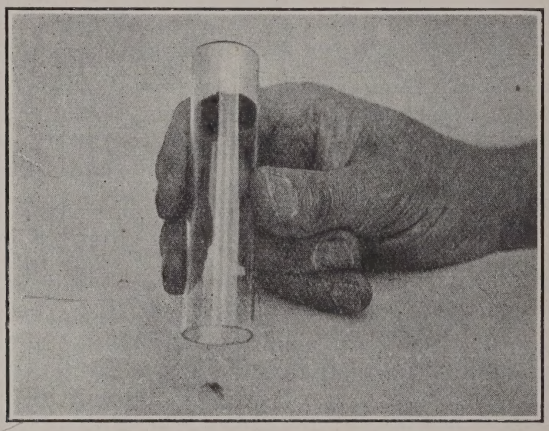

Fig. 10. Catching a mosquito in a killing tube.

Even during the *larval* stage, the different species may readily be distinguished from one another by examination with a low power microscope. The siphon of every **Culicine** larva carries, on each side, a row of curious spikes collectively known as a "*pecten*" and one or more "*tufted hairs.*" As shown in Fig. 11, the relative positions of the pecten and the tufted hairs vary very greatly in different species, and thus afford a ready means of identification.

The methods of collecting mosquito *larvae* are described on pages 23, 24.*

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* Specimens of mosquito larvae and adult mosquitoes forwarded by post to the British Mosquito Control Institute will be examined and reported upon free of charge.

Larvae should be sent in a small bottle or tube (say of 2 oz. capacity) about three-quarters full of the water in which the larvae were found. See Appendix E.

Specimens of (dead) mosquitoes should be sent in a small box (*e.g.* a pill box) containing a little cotton wool.

A note should be enclosed with the specimens, giving (1) the name and address of the sender, (2) the date upon which the specimens were collected, and (3) a brief description of the kind of breeding-place in which the specimens (if larvae) were found.

Packages containing specimens should be marked "Fragile" and addressed to

The Director,
British Mosquito Control Institute,
Hayling Island, Hants.

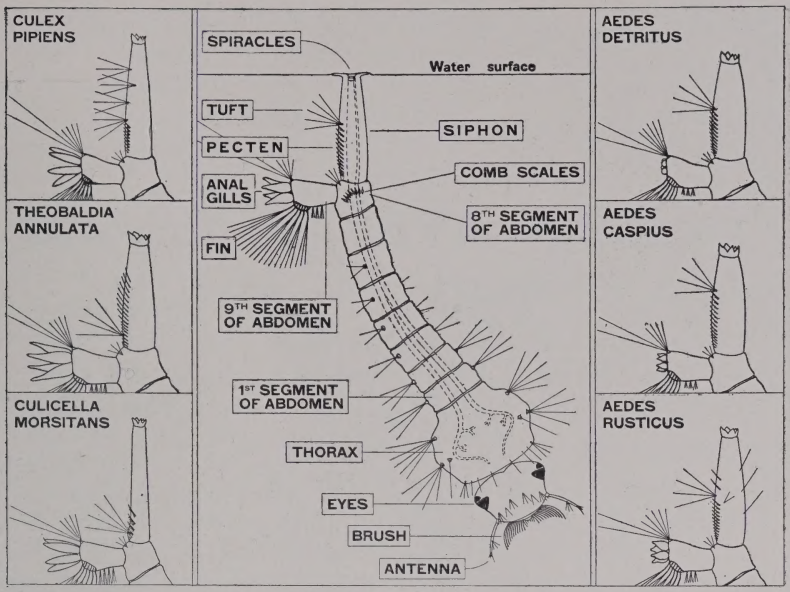

Fig. 11. *(Central Diagram).* Larva of a Culicine mosquito, showing the head and thorax *dorsally*, and the eighth abdominal segment *laterally*. Note that the "siphon" (which the larva pushes through the water surface in order to breathe) is situated on the *eighth* segment of the abdomen. The breathing organs *(tracheae)* are indicated by dotted lines. *(Side Diagrams).* Siphonal appendages and anal gills of the larvae of six common British mosquitoes. Comb scales omitted. Note that the anal gills of the salt marsh species *(Aedes detritus, Aedes caspius)* are exceptionally short. In *Aedes detritus* the hair tuft is about half way along the siphon; in *Aedes caspius* it is nearer the extremity.

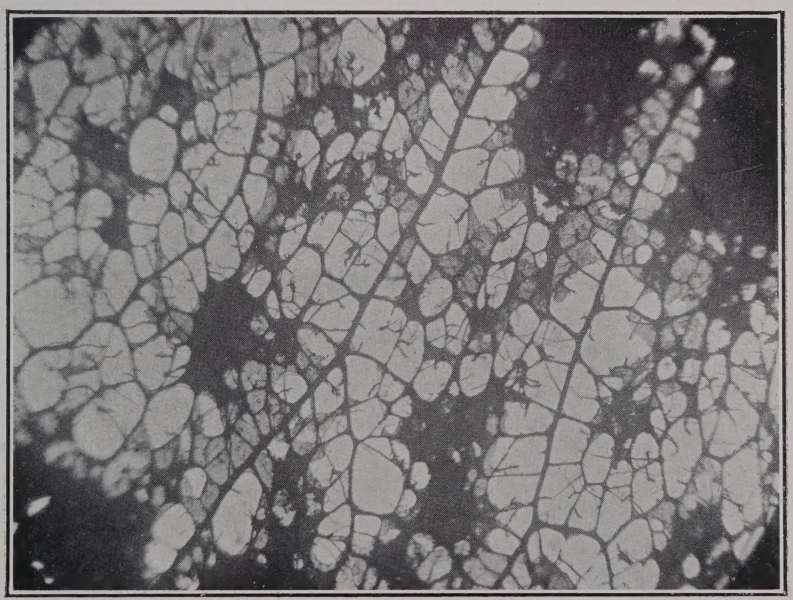

Fig. 12. Photomicrograph shewing "skeleton" of a hazel leaf, after three days immersion in a jar containing *larvae* of the rural mosquito *Aedes rusticus*. All the missing portions of the leaf were eaten by the larvae.

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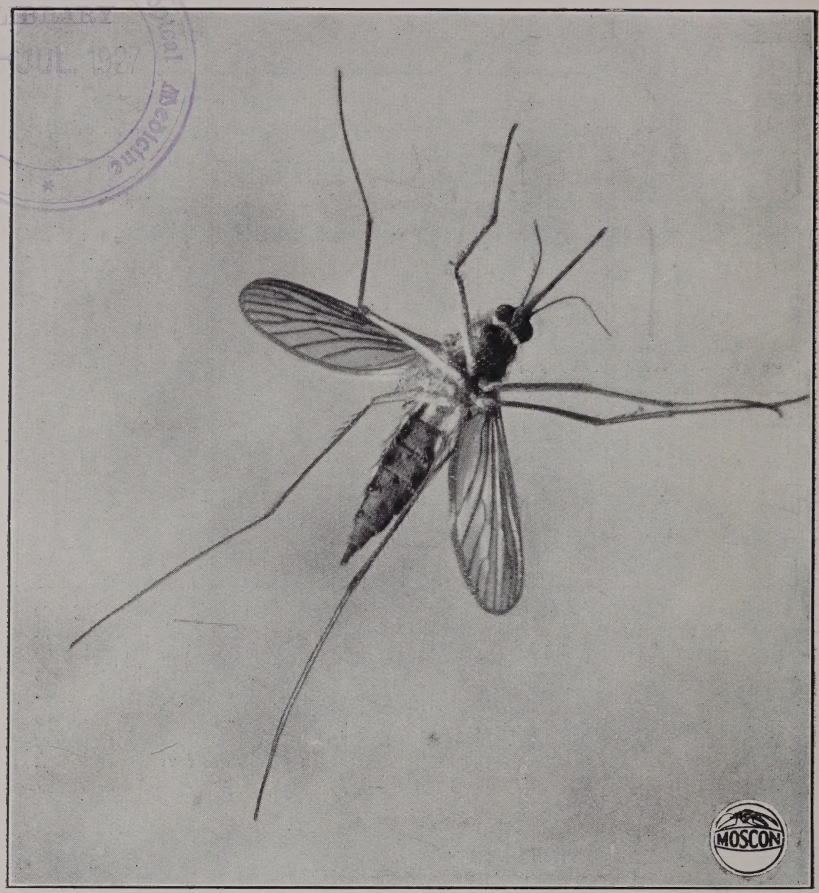

Fig. 13. Female of the **Culicine** mosquito *Aedes (Ochlerotatus) detritus.*

[About 8 times natural size.]

Viewed from below, to show the characteristic row of black spots on under side of abdomen.

Aedes detritus is one of the British mosquitoes which breed in stagnant *salt (or partly salt)* water. Another species which exhibits this peculiarity is *Aedes caspius*: but whereas the latter mosquito is occasionally found breeding in inland (non-salt) waters, *Aedes detritus* breeds exclusively in the near neighbourhood of the sea. The females of this species lay their eggs chiefly among the vegetation of coastal marshes, the eggs being able to remain in a state of suspended animation for lengthy periods* until (owing to the combined effects of rainfall, high tides, &c.) they become submerged. A certain proportion of the eggs then hatch out into larvae. Wherever sea water is allowed to accumulate and stagnate, the larvae of *Aedes detritus* are likely to be found in enormous numbers during every month of the year. The adults of this species (which under favourable conditions are produced almost continuously from April until November) have a much greater range of flight than any of the mosquitoes which breed in non-salt water (Fig. 14), the result being that this species (occasionally assisted, or replaced by, *Aedes caspius*) is usually the principal cause of the "mosquito nuisance" which is still tolerated throughout every summer and autumn in many English seaside resorts. *Aedes detritus* is easily distinguished by a "sprinkling" of white scales on the dark parts of the abdomen and legs: also by the spots on the under side shown in the above illustration.

* Observations made at Hayling Island show that these eggs are able to retain their vitality for at least a year, and probably for much longer periods.

II.

THE BRITISH MOSQUITO CONTROL INSTITUTE.

1. The Preliminary Work.

The BRITISH MOSQUITO CONTROL INSTITUTE owes its existence to the success of an "anti-mosquito campaign" which was initiated at Hayling Island, in the year 1920, to deal with the local "mosquito nuisance" which, after increasing year after year, had become practically intolerable. In the above year, the inhabitants of the central residential district found it impossible to sit in their gardens in the late afternoons or in the evenings; while spectators of outdoor games invariably provided themselves with rugs in order to protect themselves to some extent from the attacks of the pests in question.

In August, 1920, the present Director, Mr. John F. Marshall, who had undertaken to collect all possible information relating to anti-mosquito organisation, was introduced by Dr. C. G. Lamb (of Cambridge University) to Mr. F. W. Edwards (of the British Museum, Natural History), a leading authority on mosquito entomology. In a letter dated August 20, 1920, Mr. Edwards expressed the opinion that the species of mosquitoes most likely to be troublesome at Hayling were the "salt marsh" species *Aedes* (*Ochlerotatus*) *caspius* and *Aedes* (*Ochlerotatus*) *detritus*, the two British mosquitoes known to breed in brackish water. The truth of this prediction as regards the last-mentioned species was soon demonstrated—the catching and identifying of some thousands of adult mosquitoes within the central residential area during the months of September and October establishing the interesting fact that *Aedes detritus* was almost entirely responsible for the long-standing nuisance of the district.

Although, however, the bushes, hedges, long grass and other "cover" throughout the residential district were literally "packed" with untold millions of these particular mosquitoes, systematic searches in the neighbouring pools and ditches for the *larvae* of this species proved fruitless until the following year (1921), when they were discovered in enormous numbers in certain accumulations of stagnating and partly salt water lying about a mile and a half distant from the centre of the residential district where the adult

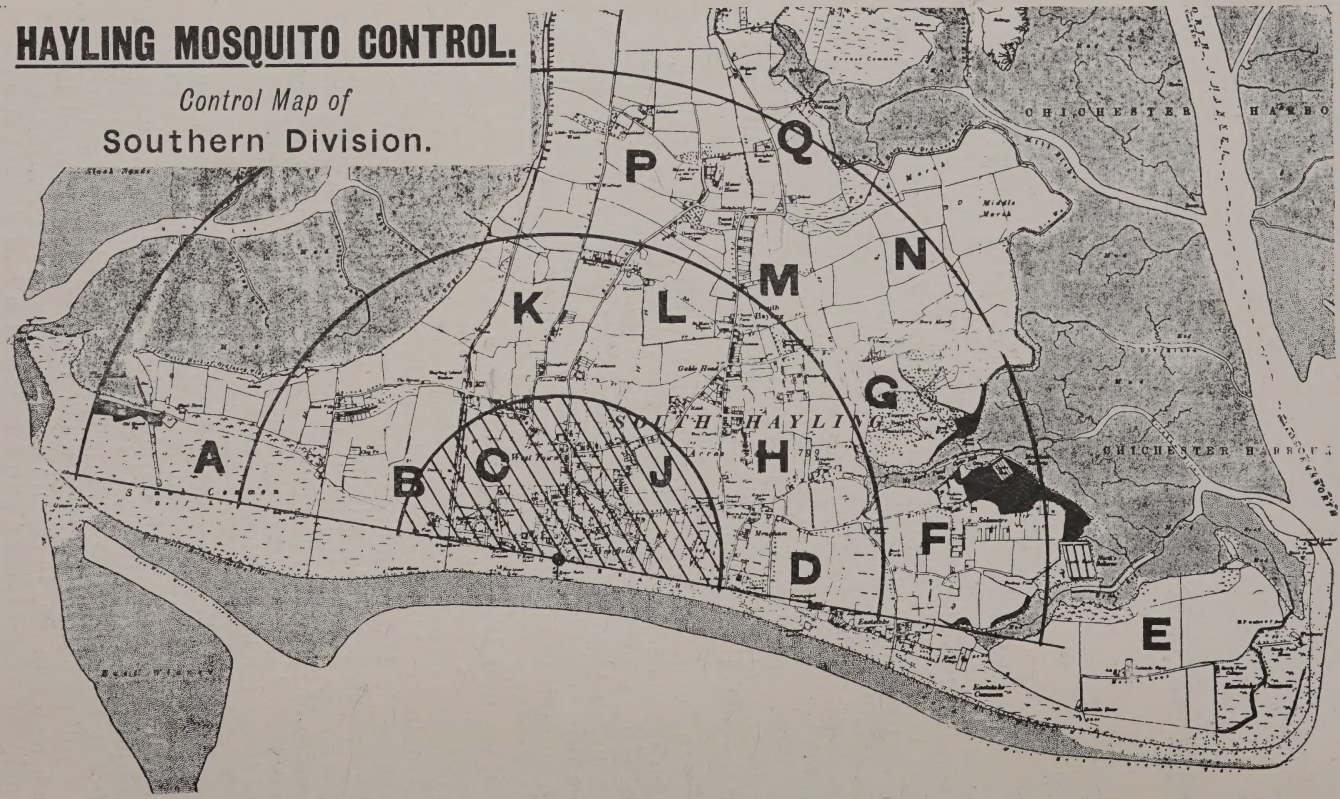

Fig. 14. Explanatory Map of South Hayling. The semicircles are *one and a half miles*, *one mile* and *half a mile* in radius; the innermost one (shown shaded) surrounds the central residential district. The portions of the map sections A, F and G indicated in black are the mosquito-breeding areas (*Aedes detritus*) which have now been either abolished or "controlled."

mosquitoes had been caught. One of the worst of these breeding places is shown in Fig. 15.

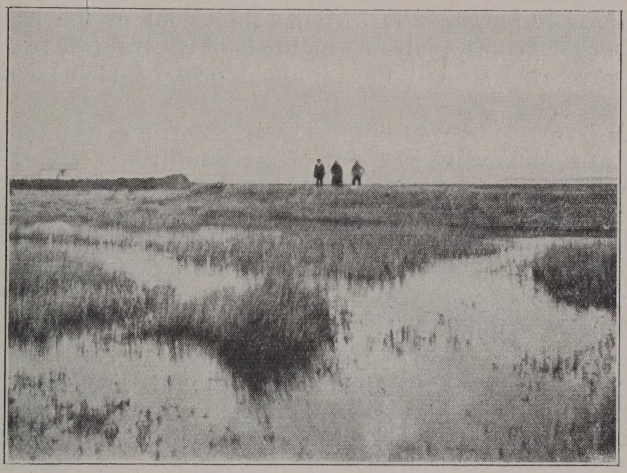

Fig. 15. Typical breeding place of the salt-marsh mosquito *Aedes detritus*.

Consideration of the above facts, supplemented by the knowledge that certain coastal mosquitoes of America were stated to have a range of flight of several miles, suggested the possibility that, if the breeding of mosquitoes could be prevented in the above-mentioned districts, the mosquito nuisance would be abated, not only in the near neighbourhood of the breeding places, but also in the more distant residential district. The state of affairs at that time is illustrated in Fig. 14, the breeding areas being shown in black, near the letters "A" and "F," and the central residential district itself indicated by the shaded semicircle of half a mile radius.

On April 13th, 1921, a meeting of some 70 inhabitants was held at "Seacourt," (Mr. Marshall's residence) to consider the possibility of instituting a systematic campaign against the mosquitoes of the district. The proposal having received unanimous approval, a number of sub-committees were elected to deal with various branches of the projected work: the central direction of the campaign being in the hands of a "General Purposes Committee" composed of Sir Richard Gregory, D.Sc., F.R.A.S. (Chairman), the late Dr. J. R. S. Robertson (Honorary Treasurer), Mr. E. M. Fletcher, M.A., Dr. A. J. May, M.B.,B.C., Mr. L. V. Turner, B.Sc., and Mr. J. F. Marshall, M.A. (Honorary Director).

It was decided that the organization should be entitled "The Hayling Mosquito Control." A circular explaining the objects of the campaign and appealing for the assistance of voluntary workers, and for financial support, was drawn up and sent to every householder on the Island.

The work of abolishing the mosquito-breeding areas already located was at once put in hand, while systematic searching for further breeding places was commenced and continuously maintained. In the treatment of the breeding places, the various available methods of control (see p. 24 etc.) were employed to suit the circumstances of each particular case.

A laboratory was improvised, in which a number of important facts were experimentally established. To give an example, the analysis of many hundred samples of "larva-infested" water showed that *Aedes detritus* would breed freely, not only in brackish water (as previously known), but also in stagnant water of salinity equal to (and even greater than) that of sea water.

In the summer and autumn months of 1921, a number of breeding places were permanently abolished, while a large number of others were treated with paraffin or larvicides. The early operations of the Hayling Control aroused considerable public interest, illustrated articles describing the work appearing in *The Sunday Pictorial* (Sept. 21, 1921), in the medical journal *Health* (Nov. 5, 1921) and in the scientific quarterly, *Science Progress* (Jan. 1922).

The article in *Health* attracted the attention of the Ministry of Health, and Colonel S. P. James, an officer of the Ministry and a well-known authority on anti-malaria organization, visited Hayling early in 1922 to inspect the work that was being carried on. During the years 1922 and 1923, Colonel James rendered much valuable assistance to the Hayling Control in many ways: in particular lending the help of his assistant, Mr. P. G. Shute, on a number of occasions in the years above-mentioned. In the year 1923, moreover, the Ministry of Health contributed a "scientific grant" of £100 towards the cost of labour employed in certain experimental work.

Throughout the years 1923 and 1924, the work of alternatively abolishing or "controlling" the mosquito-breeding areas continued uninterruptedly, the mosquito nuisance of the district decreasing in proportion, and eventually disappearing altogether. Evidence of this was furnished by a postcard "canvass" of the residential district in October, 1924: as well as by the fact that residents were able (for the first time in many years) to sleep out of doors.

The Hayling Mosquito Control was the first mosquito control organization to be set up in this country, and a certain amount of opposition was encountered for some time until it became generally realised that the work could be carried out without causing any inconvenience to individuals, and that it would benefit the community in many ways. The education of public opinion in this direction was greatly facilitated by the conversion of a disused billiard room

into a Demonstration Museum (Fig. 16), in which diagrams, maps, photographs, etc., illustrating the progress of the campaign were open to public inspection, as well as living and dead specimens of the local species of mosquitoes and their larvae. In this Museum, lectures and demonstrations relating to the various branches of mosquito control work were frequently given. The large scale map on which the progress of the campaign was continuously indicated is shown on the right.

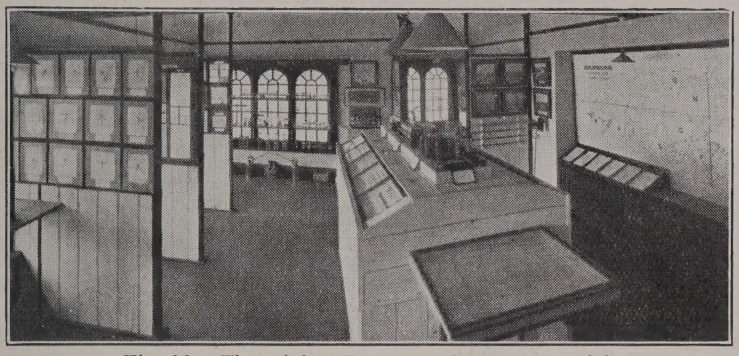

Fig. 16. The original Demonstration Museum of the Hayling Mosquito Control.

Almost from the outset much interest has been shown by professional organizations, naturalists and others in the work carried on at Hayling. When the British Medical Association met at Portsmouth in July, 1923, a party of 120 members made a special visit to the Demonstration Museum where they inspected various branches of the Hayling Control work. Since then official visits have been paid by the Zoology Section of the British Association, the Hampshire Entomological Society, the Portsmouth Literary and Philosophical Society, the Hampshire Field Club, the Bournemouth Natural Science Society, &c. In addition, many Medical Officers of Health and other scientific workers have paid personal visits to Hayling in order to acquaint themselves with the facilities offered for the practical study of mosquito control problems, so as to be able to apply the same methods in their own districts, at home or abroad.

2. *The Formation of the Institute.*

As will have been seen in the foregoing pages, the work of the Hayling Mosquito Control, though primarily concerned with the locating and abolishing of "breeding-places" of mosquitoes, became very soon extended in various other directions. In the early stages of the work the absence of sufficiently exact information, even as regards such ordinary operations as "oiling" or "larviciding" stagnant water,

necessitated the carrying out of a large number of experiments. The problem, for example, of obtaining a larvicide which would be effective when added to salt (or partly salt) water was successfully solved. It soon became manifest that further knowledge was essential in every branch of the work: each breeding area dealt with providing material for new lines of investigation. Education in regard to mosquito control matters was supplied in the first instance by means of the Control Museum (Fig. 16), this branch of the subject being eventually developed very greatly by the production of photographs, lantern slides, etc., illustrating the different species of British mosquitoes and the various methods of controlling them.

Throughout the year 1924, the inconvenience due to insufficient accommodation was more and more felt, and by the end of the year it had become obvious that, unless suitable premises were forthcoming, the work of the Control could no longer be carried on. In view of these considerations, the Director decided to erect at his own expense a separate building wherein the various branches of the work might adequately be developed: it being hoped that some scheme for establishing the organization upon a permanent basis would eventually be devised.

A site having been chosen in a field adjoining "Seacourt," with a frontage on the Sea Front, the work of construction was commenced in February, 1925.

Early in June (1925), Sir Richard Gregory, the Editor of *Nature*, who had been Chairman of the Hayling Mosquito Control Committee from the outset, approached a number of eminent scientists, in regard to the formation of a Council for the new organization, which it was proposed to entitle "The British Mosquito Control Institute." This request met with a very gratifying response.

It was subsequently decided to invite Sir Ronald Ross, K.C.B., K.C.M.G., F.R.S., a member of the Institute Council, to open formally the new building, which he most kindly consented to do.

3. The Opening of the Institute.

The opening of the British Mosquito Control Institute took place on August 31st (1925), the ceremony being attended by over 350 guests, this total comprising some 80 members of the Zoology Section of the British Association, who, together with their President, Mr. C. Tate Regan, F.R.S., had motored from Southampton, where the annual meeting of the Association was at that time in progress.

Among the guests who attended the opening were the following—

Sir Ronald Ross, K.C.B., K.C.M.G., F.R.S. *(Director in Chief, Ross Institute & Hospital for Tropical Diseases)*; Sir David Bruce, K.C.B., F.R.S. *(Chairman of the Governing Body, Lister Institute)*; Sir Arthur Newsholme, K.C.B., *(General Medical Council)*; Sir William Simpson, C.M.G. *(Director of Tropical Hygiene, Ross Institute & Hospital for Tropical Diseases)*; Sir Richard Gregory, D.SC., F.R.A.S. *(Editor of "Nature")*; Lt.-Col. S. P. James, M.D., D.P.H. *(Medical Officer and Adviser on Tropical Diseases to the Ministry of Health)*; Prof. J. H. Ashworth, D.SC., F.R.S. *(Professor of Zoology, Edinburgh University)*; Prof. S. J. Hickson, D.SC., F.R.S. *(Professor of Zoology, Victoria University of Manchester)*; Prof. A. F. C. Pollard, A.R.C.S., A.M.I.E.E. *(Professor of Instrument Design, Imperial College of Science, London)*; Dr. E. J. Allen, D.SC., F.R.S. *(Director of the Marine Biological Laboratory, Plymouth)*; Dr. F. A. Dixey, M.A., F.R.S. *(Curator of the Hope Collections, Oxford)*; Mr. C. Tate Regan, M.A., F.R.S. *(Keeper of Zoology, Natural History Museum)*; Mr. F. Balfour-Browne, M.A, F.R.S.E. *(Recorder of the Zoology Section, British Association)*; Mr. E. Heron-Allen, F.R.S.; Mr. F. A. Potts, M.A. *(University Lecturer in Zoology, Cambridge University)*; Mr. C. G. Lamb, M.A., Sc.D. *(Reader in Electrical Engineering, Cambridge University)*; Surgeon-Rear-Admiral D. W. Hewitt, C.B., C.M.G.; Lt.-Col. R. E. Drake-Brockman, D.S.O., M.D., R.A.M.C. *(Inspector for Tropical Diseases, Head Quarters, Ministry of Pensions)*; Lt.-Col. W. C. Smales, D.S.O., R.A.M.C. *(Medical Officer of Health for Gibraltar)*; Surgeon-Commander P. F. Alderson, D.P.H., R.N. *(Naval Health Officer, Portsmouth Command)*; Major N. Low, D.S.O., O.B.E., R.A.M.C., *(Army Sanitary Officer, Portsmouth Command)*; Dr. James Fairley *(Medical Officer of Health for the Isle of Wight)*; Dr. A. G. Foulerton, O.B.E. *(Medical Officer of Health for East Sussex)*; Dr. W. J. Butcher *(Medical Officer of Health for the West Sussex United Sanitary District)*; Dr. Clarence Tierney, D.SC., F.R.M.S. *(South Eastern Union of Scientific Societies)*; Dr. E. W. Lockhart Stephens, C.B.E.; Dr. S. P. Sunderland; Dr. A. J. May; Dr. A. Bosworth Wright; Dr. C. F. Routh; Dr. Dorothea Taylor; Dr. G. P. Bidder; Mr. Oswald H. Latter, M.A., F.E.S.

SIR RICHARD GREGORY, D.SC., F.R.A.S., Chairman of the Council of the new Institute, opened the proceedings with a short introductory speech, in which he referred to Sir Ronald Ross' world famous discovery regarding the mosquito transmission of malaria and to the incalculable value of this discovery to mankind.

SIR RONALD ROSS, K.C.B., K.C.M.G., F.R.S., said that he esteemed it an honour and a privilege to have been invited to open a scientific institution of a somewhat novel scope, that is, one designed not primarily for teaching, nor even primarily for investigation, but directly from a utilitarian motive. During the past five years, many of those present must have followed with interest the efforts of the founder Mr. John F. Marshall, to deal with what appears to be at first sight—if not at the first experience of it—a wholly insignificant creature, the local gnat or mosquito.

Sir Ronald then briefly dealt with the initiation of the Hayling Mosquito Control scheme and its various developments, incidentally describing the serious mosquito infestation

which existed in the district at the time of his previous visit some years before. After directing attention to the result of a postcard "canvass" of Hayling residents and to other evidence proving that the control system now in operation had entirely freed the neighbourhood from a long-standing nuisance, Sir Ronald went on to say :—

"Toward the end of last year the work was becoming so extensive and interesting that Mr. Marshall thought of establishing a special Institute in connection with it; and we are here now to view the result and to commemorate the occasion. . . . . As you will all be able to see, this new house contains a demonstration museum, a laboratory, a drawing and record office, a photographic room and a mechanical workshop, all on the ground-floor. On the first floor there are a committee room and four other rooms, which will be used as required, as, for instance, by any research-workers who may wish to avail themselves of the opportunities here given. . . . . I should like to call the attention of the numerous learned bodies which grant scholarships for scientific research to the facilities for it now obtainable here; and I hope that the new Institute will shortly be humming like a hive of scientific labourers.

"Whatever the future may hold, I am sure you will agree with me, that all this work just described has been a very meritorious adventure. The benefit of it is by no means confined to Hayling Island. Here mosquitoes cause only *annoyance* to residents and to visitors during the summer; but in most tropical countries they also carry formidable *diseases;* and in some they are positively the enemies of the human race. Now any knowledge gained regarding one variety of mosquito tends to help us in gaining knowledge regarding other species; and I have, therefore, no doubt whatever that the British Mosquito-Control Institute is destined to play its part in a much wider war than that suggested by its name. . . . . .

". . . . Our ultimate aim is to control, not only mosquitoes, but all the dangerous, or even the unpleasant pests which affect us and our crops and herds everywhere. A far ideal perhaps, but one which is quite possibly within easier reach than we now imagine. We never know what surprising progeny Science may not bring forth; and he is rash indeed who would prescribe limits to her victories. Many observations which appeared quite trivial at first have now given us immense new continents of knowledge. When Columbus first sighted a small island of the West Indies he thought merely that he had found a new route to China—he had really discovered a New World. One often wonders what the great philosophers of ancient Greece would think and say if they could behold our progress of to-day. *They* were obliged to walk or to ride over their little country; *we* can now traverse it through the air in an hour or two. *Their* poets and orators addressed them only within earshot: *we* can now listen to

Fig. 17. Exterior of the Institute.
Main Entrance and Driveway.

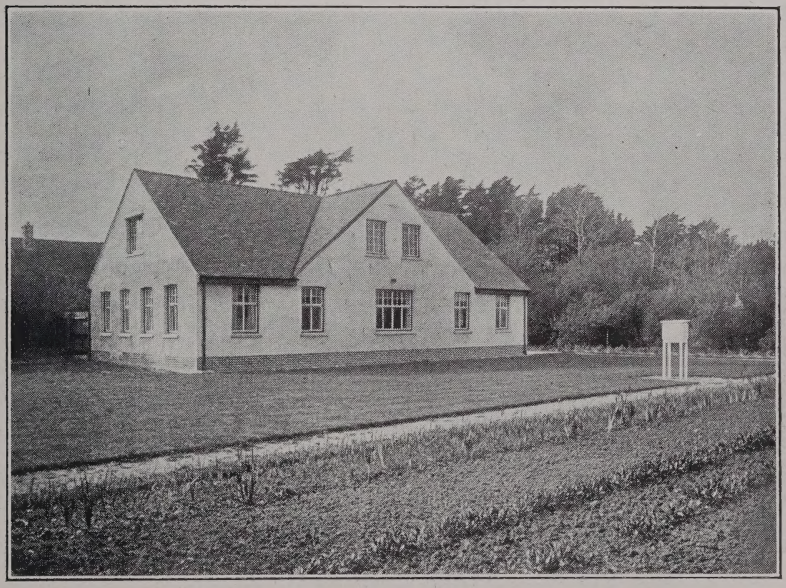

Fig. 18. Exterior of the Institute.
South and East Sides.

Facing p. 14

Fig. 19. At the Opening Ceremony, August 31st, 1925.
Sir Richard Gregory introducing Sir Ronald Ross.

Fig. 20. At the Opening Ceremony.
Sir Ronald Ross opening the new building.
Left to right: Colonel S. P. James, Sir David Bruce, F.R.S., Mr. C. Tate Regan, F.R.S., Sir Richard Gregory, Sir Ronald Ross, F.R.S., Mr. J. F. Marshall.

Facing p. 15

symphonies performed hundreds or thousands of miles distant and can read the world's news of yesterday in our newspapers every morning. So, also, I have little doubt that the great diseases which still oppress us or destroy us by millions will some day fall into our power, or, indeed, be entirely banished from among us. Even if this be too optimistic a hope, yet we shall do well at least to reach towards it. It is ridiculous that mankind, who have extended their dominion over the earth, the sea and the air, should continue to be the prey of bacilli, and should even die of such contemptible things as colds in the head and mosquito-bites!

"But in order to enlarge our dominion over these small, but deadly enemies, we must begin by enlarging our ambition. We must no longer be content to sit and sneeze with our feet in hot water, or to provide Lord Mayors' banquets to mosquitoes, or to lie down and die in the presence of a micrococcus one ten-thousandth part of an inch in diameter. What mean creatures we must be if we are to be conquered by such mean things as these! Yet this is almost exactly our position to-day. It is true that during the last eighty years the average length of human life in this country has been prolonged by about fifty per cent., chiefly by means of improved medical and sanitary science and administration; but we still die of many diseases which will probably be conquered some day. Why not accelerate the progress of this science by all the means in our power? As I have often pointed out, we in this country are now spending only a small sum on medical research, apart from education, hospitals and ancillary services. I estimate that each Briton is now giving for medical research, on the average as much as one penny a head once a year! Think of it—what generosity for matters of life and death, regarding ourselves, our children, and the whole nation! To supplement this paltry sum, instead of putting our own hands in our own pockets, we call upon private philanthropists to help us. A single bottle of whisky or a single leg of mutton costs us twelve times as much as each of us now spends on medical research during a whole year. I always maintain that the people of this country would be wise to lay out at least one million pounds a year on medical research alone, instead of one-fifth of that sum which they give at present. Even one million pounds a year would be trivial compared with the money which we now spend on alcohol, tobacco and entertainments—not to mention education, armaments and doles. After all, our health and our lives are, perhaps, the most important matters which concern us.

"But, as I have already said, the object of this fine new Institute is, primarily, not medical but general—though I have no doubt that it will always keep the sanitary applications of mosquito-control always within range of its vision, if only

upon its horizon. In all directions, knowledge dovetails in with other knowledge. Mosquito-control here will facilitate mosquito-control in the most pestiferous regions of the earth; and the day may come—indeed, I am sure that it will come—when all those fertile tracts of the world which are now dominated and ravaged by King Malaria and King Mosquito will be laid open to civilisation. But this happy result will only be attained by more thought, by more research and by a firmer determination to make the most of the beautiful world in which we live.

"In the past, nearly all scientific discoveries, like the masterpieces of literature, have been free gifts bestowed by private individuals upon the whole of humanity, not only of to-day but also of the future. Let us then, at least, give our thanks to those who endeavour to assist the footsteps of progress towards any higher ideal and wider perspective.

"I have great pleasure in declaring the British Mosquito Control Institute now open; and should add that it has found favour in the eyes of that august body, the Ministry of Health, and is ready to advise anyone whose house is suffering from the mosquito-plague and who will write to the Director on the subject. I wish the Institute every possible success in the future, and venture to suggest as a motto for it the words *Pax et Labor*."

Mr. C. TATE REGAN, M.A., F.R.S., Keeper of Zoology, British Museum (Natural History), moved a vote of thanks to Mr. and Mrs. Marshall for their reception of the company.

Colonel S. P. JAMES, M.D., Medical Officer and Adviser on Tropical Diseases to the Ministry of Health, who seconded the vote of thanks, said that the Ministry greatly appreciated the good work done by Mr. Marshall, and were determined to give the Institute every help in their power. The success of the administration of public health was largely due to the voluntary assistance which the Government received from public-spirited men and women. Mr. Marshall had advanced upon his local services by initiating in the Institute a more important and more general line of effort, and the Ministry of Health would watch its working with great, and, he hoped, helpful interest.

Mr. MARSHALL briefly responded, after which Sir RONALD ROSS declared the Institute open.

4. *General Description of the Institute.*

The British Mosquito Control Institute building, which is 130 yards from the sea shore, facing west, is 55 feet long and 32 feet wide. The walls are of brick, "roughcast" and whitened, surmounted by a roof of brown tiles. Specially designed steel-framed windows are fitted throughout. The building is centrally heated by hot water, the rooms having one, two or three radiators according to size. Electric current for lighting and power is obtained from the local mains at a voltage of 240; a transformer with a subdivided secondary winding providing current at voltages of 100, 75, 50 and 25 for special purposes.

The cost of the building and internal fittings was £3000: and that of the equipment (apparatus, specimens, books, pictures, &c.), £1200.

The ground floor plan of the Institute is shown below :—

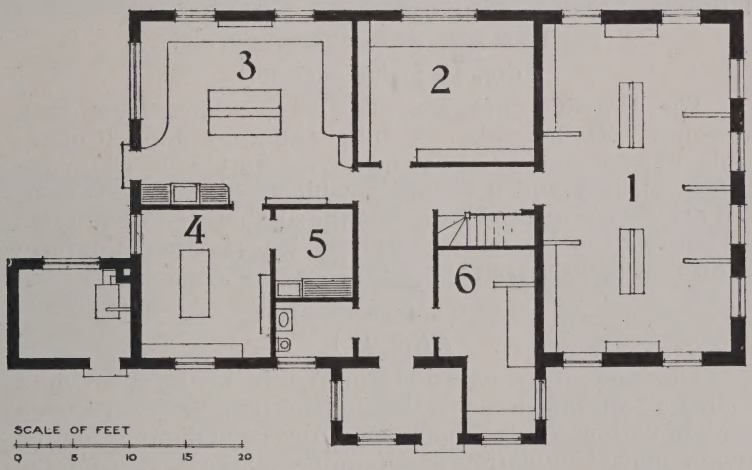

Fig. 21.

The Institute contains eleven working rooms, six of these being on the ground floor. The ground floor rooms are (1) The Demonstration Museum, (2) The Drawing and Record Office, (3) The Laboratory, (4) The Photographic Room, (5) The Dark Room and (6) The Workshop. On the first floor are (7) The Library, (8) The Projection Room, (9) The Secretarial Office and (10, 11) two other rooms suitable for special research work.

The equipment of the principal rooms is as follows :—

THE DEMONSTRATION MUSEUM.

(Figs. 22 and 44.)

The Demonstration Museum, which measures 29ft. by 17ft., has eight windows, four of which are in the south wall. In the spaces between the four south windows, there are vertical "screens" (at right angles to the wall) carrying on each side framed photographs, maps, diagrams, etc. relating to various branches of mosquito control organization. On the north wall are the large-scale maps upon which the progress of of the local control work is continuously indicated by attached discs of various colours,* the maps being protected by sliding glass panels, to prevent accidental displacement of the discs. The centre of the Museum is occupied by sixteen glazed cases, carried on two pairs of rigid supports, containing specimens of the various British mosquitoes and of other insects requiring consideration in connection with mosquito control work. Among other exhibits may be mentioned various forms of apparatus employed in the different branches of mosquito control work, lantern slides illustrating the British mosquitoes and their special characteristics, and living specimens of mosquitoes and their larvae.

THE DRAWING AND RECORD OFFICE.

(Fig. 43, facing page 30.)

The Drawing and Record Office, which faces east, measures 16ft. by 13ft. A fully equipped draughtsman's table extends from end to end of the east wall, while the north wall is occupied by filing cabinets for correspondence and records of various kinds. On the south wall are exhibited the various publications issued by the Hayling Mosquito Control during the past six years.

THE LABORATORY.

(Fig. 23.)

The Laboratory, which measures 19ft. by 16ft., provides facilities both for educational demonstrations and for research work of various kinds. Improved forms of apparatus for the microscopic examination of mosquitoes, larvae, etc.: for the "mounting" of adult mosquitoes : and for the determination of the salinity, hydrogen-ion concentration and other data relating to the water of breeding places, have been designed. On the central table will be noted a row of glass tanks, in which experiments relating to mosquito larvae are made, as well as experimental cages for adult mosquitoes. These cages, though of various patterns for different purposes, are interchangeable, any one of them being instantaneously attached to any other one, as well as to any of the experimental tanks.

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* Full details of this method will be found on pages 29, 30.

Fig. 22. The Demonstration Museum.
General View.

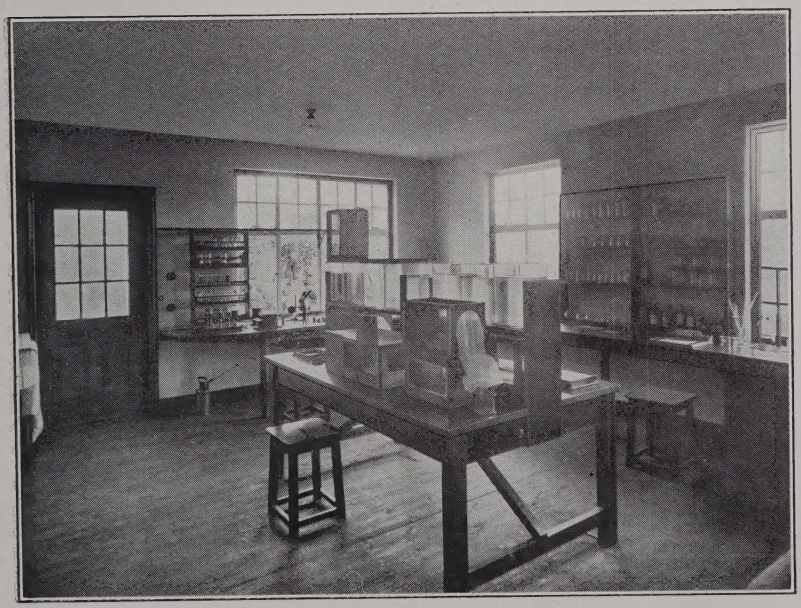

Fig. 23. The Laboratory.

Facing p. 18

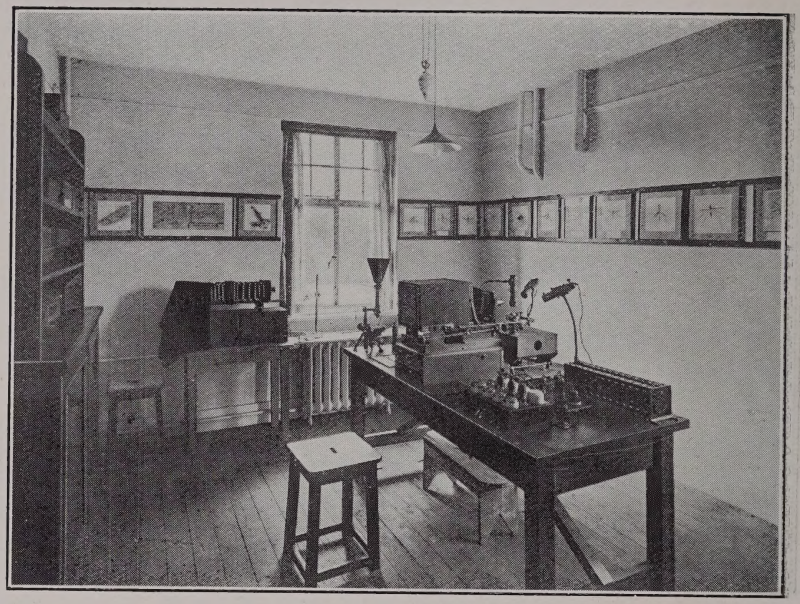

Fig. 24. The Photographic Room.

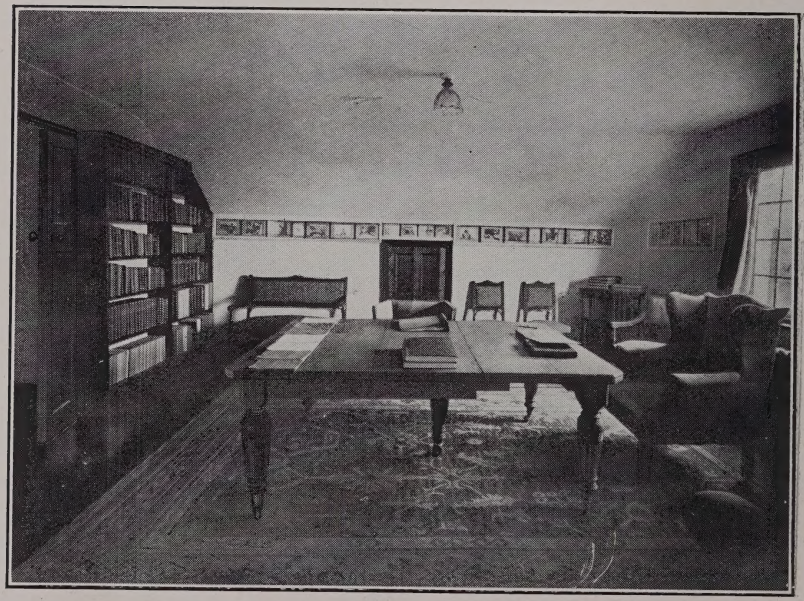

Fig. 25. The Library.

Facing p. 19

THE PHOTOGRAPHIC ROOM.

(Fig. 24.)

The Photographic Room which is entered from the Laboratory, measures 13ft. by 12ft. It is equipped with various pieces of apparatus for photographing insects in their different stages of development. The apparatus which occupies the centre of the table was specially designed by the Director as the result of several months experimenting in insect photography. By means of this apparatus (which is the only one at present in existence) it has been found possible, for the first time, to show the body markings and the wing venation of insects with equal distinctness in the same photograph. The insect is posed on a horizontal glass disc, and illuminated from above and below simultaneously : a prism, fixed perpendicularly above the insect, enabling the camera to be used with its axis horizontal. With the camera fully extended, a magnification of about 7 is obtained.*

This apparatus, with which stereoscopic photographs of insects can also be produced, has already been made use of for photographing a large number of insects (including several species of British mosquitoes) which have have never been previously illustrated.

The equipment of the Photographic Room also includes a Leitz photo-micrographic camera for use when high magnification is necessary, as well as other cameras and apparatus required for special branches of the work.

A well arranged Dark Room (8ft. by 7ft.) opens out of the Photographic Room.

THE LIBRARY.

(Fig. 25.)

The Library, which measures 17ft. by 15ft., is on the first floor, with windows on its south and west sides. A comprehensive selection of books, pamphlets, etc., relating to the control of mosquitoes and other insects, has already been acquired, in addition to a number of up-to-date works on entomology, chemistry, engineering, botany, photography and various other subjects with which the work of the Institute is necessarily concerned.

Among the periodicals which are taken in are :—

"Transactions of the Royal Society of Tropical Medicine and Hygiene." "Annals of Tropical Medicine and Parasitology." "The Journal of Tropical Medicine and Hygiene." "Bulletin of Entomological Research." "Review of Applied Entomology." "The Entomologist." "Transactions of the Entomological Society." "Journal of the Royal Army Medical Corps." "Journal of the Royal Meteorological Society." "Nature."

* An illustrated description of this apparatus appeared in "The Bulletin of Entomological Research," August, 1924.

5. *Constitution and Membership of the Institute.*

By a Licence granted by the Board of Trade on February 12th, 1927, The British Mosquito Control Institute was incorporated as "A Company limited by guarantee and not having a share capital."

The objects for which the Institute has been established are particularized in the following (3rd) Clause of the Memorandum of Association :—

(*a*) The furtherance of experimental, educational and research work in connection with mosquitoes or other noxious insects particularly with a view to advising upon and undertaking the practical measures required to control them.

(*b*) To develop and carry on the experimental, educational and research work hitherto carried on at the Laboratory at "Seacourt," Hayling Island, under the direction of Mr. John Frederick Marshall, and in the Island of Hayling generally and elsewhere.

(*c*) To provide at the aforesaid Laboratory or elsewhere an educational establishment where the habits of mosquitoes and other noxious insects may be studied with a view to their extermination.

(*d*) To provide an opportunity for those whose occupation entails living in countries infested by poisonous or poison-bearing insects, of studying the habits and life history of such insects and perfecting the system or systems found most effectual for their destruction.

(*e*) To collect, prepare, print, publish, issue and circulate and assist in the preparation, printing, publication, issue and circulation of lectures, books, journals, documents, pictures, prints, photographs and lantern slides relating to the work of the Institute and entomology.

(*f*) To receive money for services rendered to local and other bodies or individuals in connection with the destruction of mosquitoes and other insects and to accept and charge for advertisements in any publication issued by or with the authority of the Institute.

(*g*) To further the study of all branches of economic entomology.

(*h*) To accept any bequest, gift or donation towards or to accumulate and provide a fund or an endowment and to invest the same and apply the income arising therefrom or to resort to the capital thereof for any of the objects of the Institute.

(*i*) To purchase, hire, exchange, borrow, accept a gift or donation of, acquire by lease or otherwise and also temporarily or permanently for the purposes or advantages of the Institute (so far as the law shall allow and subject to the Licence of the Board of Trade where required) any real or personal property, and in particular any lands, buildings, rooms, furniture, fittings, apparatus, appliances, conveniences and accommodation, and to sell, demise, let, mortgage and otherwise dispose of the same.

(*j*) To permit any of the buildings of the Institute for the time being under its control to be used either gratuitously or on such terms and conditions as the Institute may think fit for public and other meetings, classes and discussions or any other purpose that the Institute may think expedient for or in connection with the furtherance of its objects.

In accordance with the Memorandum of Association, all funds received on behalf of the Institute must be devoted entirely to promoting the objects above specified.*

The signatories to the Memorandum and Articles of Association of the Institute are as under :—

L. W. NORTH HICKLEY	**Solicitor.** **10 King's Bench Walk, Temple, E.C.**
W. J. SIMPSON	**C.M.G., M.D., F.R.C.P., D.P.H.. Director of Tropical Hygiene, Ross Institute and Hospital for Tropical Diseases.** **Putney Heath, S.W.15.**
R. A. GREGORY	**D.Sc., F.R.A.S., F.Inst.P., Editor of "Nature"** **3, Whitehall Court, Westminster, S.W.**
HARRY ELTRINGHAM	**M.A., D.Sc.** **Woodhouse, Stroud, Glos.**
E. B. POULTON	**M.A., D.Sc. (Oxon), F.R.S., Hope Professor of Zoology in the University of Oxford, Fellow of Jesus College, Oxford.** **Wykeham House, Oxford.**
ANDREW BALFOUR	**C.B., C.M.G., M.D., D.P.H., F.R.C.P.E., Director London School of Hygiene and Tropical Medicine** **37, Torrington Square, London, W.1.**
C. M. WENYON	**Director-in-Chief, Wellcome Bureau of Scientific Research** **25 to 28 Endsleigh Gardens, W.C.1.**
S. P. JAMES	**Medical Officer and Adviser on Tropical Diseases, Ministry of Health, London**
A. E. SHIPLEY	**G.B.E.,Sc.D., F.R.S., Master of Christ's College Cambridge, Vice-Chancellor of the University, 1917-19.**
JAMES CRICHTON-BROWNE ...	**M.D., L.L.D., F.R.S., D.Sc., Late Lord Chancellor's Visitor, Vice-President Royal Institution of Great Britain, late President Sanitary Inspectors' Association** **45 Hans Place, S.W.**
GUY A. K. MARSHALL	**C.M.G., D.Sc., F.R.S., Director of the Imperial Bureau of Entomology, British Museum.**
E. E. AUSTEN	**D.S.O., F.Z.S., Major, 2nd Battn. Lond. Regt. (Retd.) Deputy Keeper, Department of Entomology, British Museum.**
FRANK BALFOUR BROWNE ...	**M.A., F.R.S.E., F.Z.S., F.E.S., Professor of Entomology, Imperial College, London.**
JOHN F. MARSHALL	**M.A., F.L.S., Seacourt, Hayling Island, Hants.**

* Clause 4 of the Memorandum of Association states that "the income and property of the Institute whencesoever derived, shall be applied solely towards the promotion of the objects of the Institute as set forth in this Memorandum of Association, and no portion thereof shall be paid or transferred directly or indirectly, by way of dividend, bonus or otherwise howsoever by way of profit to the members of the Institute."

As previously stated (p. 7), the British Mosquito Control Institute is the outcome of an anti-mosquito campaign which was initiated in Hayling Island (Hampshire) in the year 1920, under the title of the Hayling Mosquito Control. The work of the latter organization has been supported by contributions from local authorities and residents, amounting to about £150 annually; all subscriptions thus received being expended in respect of materials, outside labour, &c., required for the purpose of controlling mosquitoes in Hayling Island only. From August 31st, 1925, until recently, the research work of the Hayling Mosquito Control has been carried on in the laboratory of the British Mosquito Control Institute; the two organizations being kept, however, entirely distinct from one another.

At a meeting of the Council of the Institute, held in London, on March 30th, 1927, it was decided:—

(i) that the Hayling Mosquito Control should in future be known as the Hayling Island Branch of the British Mosquito Control Institute;

(ii) that in view of the fact that the work of the said Hayling Island Branch was being directed, and to a large extent carried out, by the Institute staff, *one-fourth* of the funds locally subscribed should be allocated to the Institute, and the remaining *three-fourths* expended upon materials and outside labour required for the purposes of the local work;

(iii) that, in the event of additional Branches of the Institute being formed in other parts of the country, a similar apportionment of the funds subscribed for the purposes of such Branches should be made.

Up to the present the British Mosquito Control Institute, which is occupied with research and educational work of various kinds relating to mosquito investigation, has not (as is generally assumed) received any financial assistance from official bodies or from local authorities, but has had to rely almost exclusively upon voluntary contributions either in the form of donations or of membership subscriptions.

The Articles of Association provide for the election of (a) Life Members, who contribute one payment of £10, and (b) Annual Members, who subscribe £1 1s. 0d. yearly.

The liability of each Member is limited to £1.†

It is hoped that a sufficient number of Members may be obtained to provide an annual income which will enable the work of the Institute to be carried on efficiently.

Forms of Application for Membership, &c., will be found at the end of this Handbook.

† Clause 8 of the Memorandum of Association states that "Every member of the Institute undertakes to contribute to the assets of the Institute, in the event of the same being wound up during the time that he is a member or within one year afterwards, for payment of the debts and liabilities of the Institute contracted before the time at which he ceases to be a member, and of the costs, charges, and expenses of winding up the same, and for the adjustment of the rights of the contributories amongst themselves, **such amount as may be required not exceeding £1.**"

III.

SOME PRACTICAL DETAILS OF MOSQUITO CONTROL ORGANIZATION.

1. Introductory.

As previously stated (p. 4), any collection of stagnant water, whether non-salt† or salt, is likely to be infested with the larvae of one or more species of mosquitoes. Salt marshes, woodland pools, tree holes, roadside ditches, badly drained stable yards and even discarded tins and bottles filled with rain water must be regarded alike with suspicion. A further difficulty is introduced by the fact that several species of British mosquitoes lay their eggs on dry ground—instinctively selecting hollows or low-lying areas which are destined to fill with water during the wetter months of the year. Pools, ditches, etc. which dry up during the summer months must therefore be kept under observation, in order to ascertain when they become re-filled with water.

The want of some general term applicable not only to all kinds of places in which water **has collected** but also to those in which it **is liable to collect** is frequently noticeable in the literature of mosquito control work. The expression "**potential breeding place,**" which is most frequently employed, is not only cumbersome but also, in many cases, unsuitable. The term "**water-place**" was adopted by the Hayling Mosquito Control Committee about five years ago.‡

The routine operations of a Mosquito Control Organization—or as it is frequently termed for brevity, a Mosquito Control—fall naturally into three main divisions, namely:—

A. Inspection of water-places and subsequent identification of the species of any larvae found.

B. Application, where necessary, of the methods of "control" most suitable in each particular case.

C. Recording the details of the work done, the results attained, the scientific data collected and so on. This may be called the "Central Station Organization."

2. Inspection of water-places, etc.

The presence of *Culicine* larvae in stagnant water is easily detected, fully grown specimens hanging head downwards under the surface being clearly visible to the unaided eye: but *Anopheline* larvae which lie horizontally, and often under shelter of surface vegetation, are not so readily discerned (Fig. 47). Mosquito larvae may be collected by means of a white dish or handbowl, as shown in Fig. 26, care being taken not to give them any

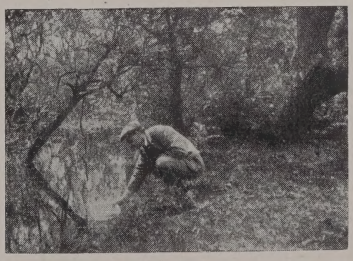

Fig. 26.

† As mosquito larvae are often (and in the case of some species *usually*) found in extremely filthy "fresh" water, the words "non-salt" should always be used in mosquito control literature in preference to "fresh."

‡ The adoption of this expression was first publicly advocated in an article contributed by the author to the scientific quarterly "*Science Progress*," January, 1922.

preliminary warning, as they quickly dive out of sight when alarmed. A better way of collecting larvae is to use a long-handled ring net of muslin with a small glass collecting tube attached, generally known as a "pond life net." (Figs. 27 and 28). Such a net may easily be improvised with

Fig. 27.

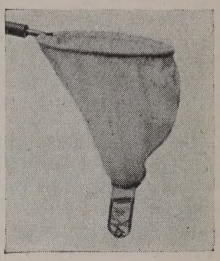

Fig. 28.

any wide mouthed bottle, an old handkerchief and a piece of wire. The most useful form of pond life net is one whose handle may be lengthened when required by screwing on additional sections.

When larvae are found in any water-place, their species must be identified, by examining the appendages of the larval "siphons"* as previously explained (Fig. 11). When the larvae are in an advanced stage of growth, the examination can be made satisfactorily by means of a fairly powerful pocket lens; but as a matter of routine it is preferable to transfer each batch of larvae to a storage tube and examine them later with the compound microscope at the laboratory. A knowledge of the species discovered in each water-place is important for many reasons. For one thing, some species of mosquitoes appear in the adult form earlier in the year than other species and it is obviously advisable, as a general rule, to give prior attention to the breeding places which are, so to speak, "next on the list" as regards the output of adult mosquitoes.

It is important to note that long-established collections of water such as cattle ponds, ornamental lakes, etc., frequently contain fish, water bugs and various kinds of insect larvae which devour the eggs and larvae of mosquitoes and thus render impossible the production of adult mosquitoes. In such cases, the addition of larvicide is not only unnecessary but may actually do harm by destroying some, or all, of the benevolent "mosquito enemies" which are assisting the work of the controller. **Hence water should never be treated with larvicide unless the presence of larvae has been actually observed.**

3. *Application of Control Methods.*

As already explained (p. 4) the breeding of mosquitoes may be prevented either by (i) **oiling** (ii) **larviciding** or (iii) **engineering** their *larvae* out of existence, according to the circumstances of the case.

(i) The method of killing the larvae by spraying the water surface with paraffin or other oil, and thereby suffocating the larvae, has been employed with great success, and often on a very large scale, in many parts of the world—and numberless devices for applying the oil under different imposed conditions have been described.

For treating breeding places of comparatively small size, a small "one handed" pneumatic sprayer (such as is used by fruit growers) is extremely useful. As regards the amount of paraffin required to treat a given expanse of water, experiments made in Hayling in the year 1921 showed that one pint of paraffin should be used for every 40 square yards of surface.†

* Except in the case of *Anopheline* larvae, which have no siphon. The larvae of the three British members of the *Anopheline* tribe are easily differentiated by examining certain hairs on the head.

† See Appendix C.

The surface-oiling method has, however, certain serious limitations. The production of a sufficiently lasting film is sometimes an impossible task, notably in cases where the water surface is broken up by growths of weeds, or is too freely exposed to the wind. In the case of mosquitoes whose breeding places are located in the near neighbourhood of the sea (and which are in all probability the most serious "nuisance-producers" in this country) this method must be regarded as of no practical value.

(ii) The alternative method of killing larvae is by using a "larvicide," that is to say, by putting some chemical substance into the infested water so as to poison the larvae. An enormous number of different substances—solid, liquid, and even gaseous, have been recommended in text books as suitable larvicides: but the vast majority of these stand self-condemned owing to the prohibitive cost that would be entailed by employing them in the prescribed "strengths" on any practical scale.

For a larvicide to be of any practical use in mosquito control work it must satisfy three conditions. FIRST it must be inexpensive; SECONDLY it must be harmless to human beings or animals who may happen to drink the water treated; and THIRDLY, it must be effective in action whether the stagnant water to be treated is non-salt or salt.

As the result of some experiments made in Hayling some years ago, it was found that a certain sanitary fluid containing 20 per cent of soluble cresol fulfilled the above-mentioned requirements very satisfactorily. One gallon of this fluid will effectively kill all mosquito larvae in 28,000 gallons of water—the quantity of this larvicide required in any particular case being easily calculated by multiplying the area of water surface (expressed in **square yards**) by the average depth (expressed in **inches**) and dividing the product by 6000. The figure thus obtained is the number of gallons of larvicide required.*

When adding a larvicide to any collection of stagnant water, care should be taken to distribute it as uniformly as possible. In any case it is advisable to dilute the total "dose" with 3 or 4 times its bulk of fresh water, and then introduce the mixture by instalments. One way is to use a watering can with a rose nozzle; the operator wearing waders and treating consecutive strips of the water. Another very effective method is to throw the successive instalments of the mixture out of an ordinary handbowl (Fig. 29), very little practice being required to distribute the mixture rapidly and uniformly in this way.

Fig. 29.

(iii) As already mentioned, however, the destruction of mosquito larvae by oil or larvicides must only be regarded as a temporary expedient; **mosquito breeding-places should be permanently abolished by appropriate engineering methods whenever it is possible to do so.**

In the majority of cases, a mosquito breeding-place consists of a cavity or depression in the ground containing some kind of stagnating water. Such a breeding-place can be put out of action

(I) **by removing the water altogether** or
(II) **by preventing its stagnation.**

---

* See Appendix C.

It is obvious that the first plan (I) can be carried out either

(a) by filling the cavity with earth or rubbish, or

(b) by draining away the water.

The second plan (II)—namely that of, so to speak, "un-stagnating" the water—is the one that must generally be adopted in the case of neglected field or roadside ditches, which are often the main cause of mosquito infestation, especially in low-lying districts where surface drainage channels have to be constructed with insufficient fall and are therefore easily blocked. The breeding of **Culicine** mosquitoes in a blocked ditch is immediately remedied by removing the obstructions which prevent the water from flowing (Fig. 30). It must be remembered, however, that the larvae of certain species of **Anopheline** mosquitoes are able to develop in *slowly-running* water, if provided with an anchorage of surface vegetation. *(See footnote, p. 3).*

Fig. 30.

In low-lying coastal districts particular attention must be given to **cavities** and **enclosures** in "intertidal areas," that is to say, in areas lying between the levels of ordinary high and low tides. Accumulations of stagnant and partly salt water are generally to be found in intertidal enclosures, owing to the oozing of the sea through defective sluices and sea walls. When cavities or enclosures of this kind are of comparatively small size, **they should either be filled up with earth or given free communication with tidal water.** Figure 31 shows some small, but

Fig. 31.

very badly infested, breeding-places being connected up with an adjoining creek. As soon as a simple operation like this is completed, mosquito breeding is no longer possible, since there are a number of causes which prevent the larvae even of salt marsh mosquitoes from existing in tidal water.

In many cases, however, intertidal enclosures are so extensive that it would be much too costly to fill them in, and equally impracticable to allow the sea to cover them at every high tide. In this case the most usual procedure is to construct a system of ditches linking up all the separate breeding-places and communicating with a sluice gate or valve which can be opened (or which will open automatically) when the tide is sufficiently

Fig. 32. A typical breeding area of the salt marsh mosquito *Aedes detritus*. Waterlogged grass land near the sea shore.

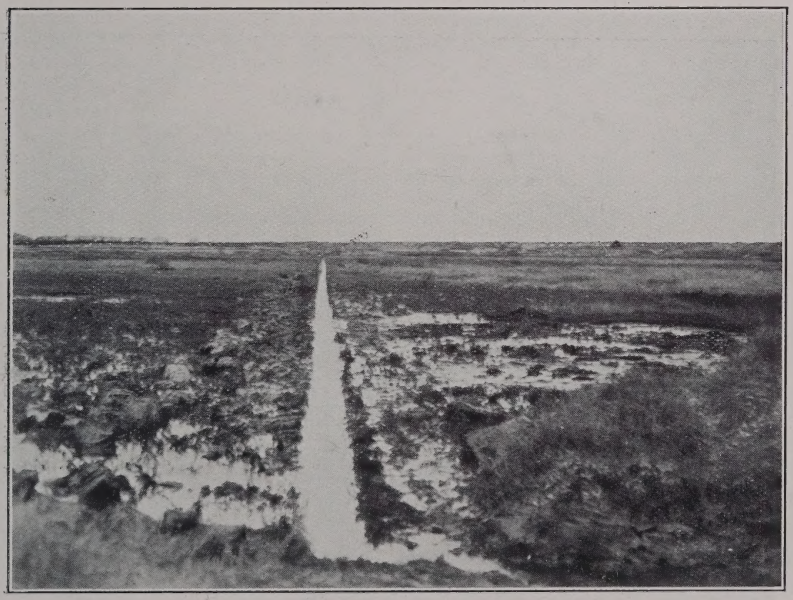

Fig. 33. Stagnant salt water draining out of an intertidal enclosure during a low tide. The ditch leads to a hand-operated sluice in the distant sea wall.

Facing p. 26

Fig. 34. Detached pools of stagnant salt water, formed by leakage through a sea wall (right) and infested with the larvae of *Aedes detritus*.

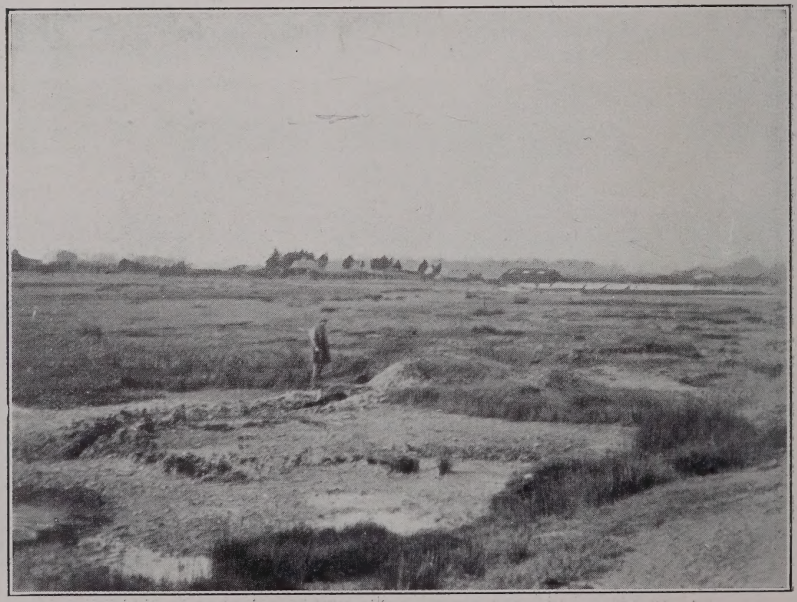

Fig. 35. The area shown in Fig. 34, after the separate pools had been connected together and the infested water drained away through a sluice during low tide.

Facing p. 27

low.* (Figs. 33, 34, 35). A common type of hand-operated sluice valve is shown in Fig. 36.

Fig. 36.

Wherever sea water is allowed to accumulate and stagnate, the larvae of the salt marsh mosquito (*Aedes detritus*) are likely to be found in enormous numbers throughout every month of the year. The adults of this species (which hatch out almost continuously from April until November) have a much greater range of flight than any of the non-salt water mosquitoes; and this fact considerably increases the difficulties of mosquito control work in low-lying coastal districts. It may be stated definitely that the "mosquito nuisance" experienced in so many of our seaside resorts is most frequently caused by **salt marsh** mosquitoes invading the residential district from breeding-places situated on the outskirts of the town. Hence the attempts occasionally made by local authorities to alleviate the nuisance by paraffining collections of stagnant water **within the residential district only** are in the majority of cases to be deprecated; not only because they are a sheer waste of public money, but also because their futility tends to diminish public confidence in anti-mosquito work generally.

4. Central Station Organization.

The question is often asked why—having regard to the fact that information as to the control of mosquitoes is both easy to obtain and to utilise—so few successful attempts have so far been made to deal with the numerous mosquito-infested districts in this country. The explanation appears to be that work of this kind is generally commenced in a haphazard sort of way, and with an entire lack of the systematic organization required for applying the various remedial measures available with sufficient thoroughness to ensure the success of the campiagn.

It is important to remember that, generally speaking, the mosquito infestation of any given district is approximately proportional to the quantity of stagnant water which is permitted to exist in the locality. Hence mosquitoes tend to be prevalent in low-lying districts and to be comparatively rare in hilly ones. As already stated, the "mosquito control" of a district is effected by either (i) abolishing, (ii) un-stagnating, (iii) oiling or (iv) larviciding, according to circumstances, as many collections of stagnant water as possible: and the more comprehensively is this work carried out, the greater will be the immunity from annoyance. The permanent eradication of mosquitoes from even a limited area is, however, a matter of impossibility. Even during the winter months, the continuity of existence of mosquitoes is being carried on in three separate stages of development, namely (i) unhatched eggs, as yet out of contact with water, (ii) slowly-growing larvae in stagnant water and (iii) hibernating females in cellars, stables, &c. It has been proved by experience in many parts of the world that when, from lack of public support, the supervision of stagnant water in a controlled area is discontinued, the

* It is suggested that an area dealt with in this way should be spoken of as being "controlled," since mosquito breeding is only prevented just so long as the necessary supervision is maintained.

mosquito annoyance may be expected to recommence within a comparatively short period.

As is generally known, the Hayling Mosquito Control was the first (and is even now the *only*) example in this country of a permanent (that is to say, a *continuously operated*) scheme of mosquito control. The methods briefly described below (which are the outcome of nearly seven years' practical experience) have completely abolished the nuisance from what was formerly one of the worst "mosquito districts" along the South Coast. It seems fair to assume, therefore, that the adoption of a similar scheme in other infested districts would give equally satisfactory results; though various modifications would of course have to be made to suit the local conditions existing in each particular case.

As it is obviously impossible to conduct an anti-mosquito campaign in the absence of definite headquarters, the first thing to do is to acquire the use of some room to be devoted exclusively to the purpose of the work. The equipment of such a room, which it will be convenient to refer to as the "Control Station," need not be of an elaborate nature, the essential items being (1) a table, (2) a compound microscope, (3) some index cards for recording details of the work and (4) a large scale map of the area to be controlled, upon which the progress of the work can be continuously indicated. A sink with running water should also be provided. The equipment of the Control Station also includes, of course, the apparatus employed for collecting specimens, as well as the apparatus and implements required for dealing with the water-places found to be infested with larvae.

The value of any Control Station is greatly increased by the addition of any diagrams, illustrations, specimens, etc. of the prevalent local species of mosquitoes, together with any exhibits explanatory of the life history of mosquitoes and of the fundamental principles of control work. A few "mosquito incubators" (Fig. 37) containing larvae of the different species occuring in the district, will enable the various stages of mosquito development to be continuously watched—the adult mosquitoes which hatch out and migrate to the upper portion of the jar being fed when necessary by placing raisins or other food upon the wire netting at the top.

By allowing the public to visit the Control Station at specified times, the local interest in the campaign is greatly stimulated and much voluntary assistance thereby obtained.

The maps used in mosquito control work must be of the largest scale met with in general practice, namely those known as the 1/2500 Ordnance Survey, or 25·344 inches to the mile. These maps are obtainable in sections measuring 38 inches in length by 25 in height; and the necessary sections, mounted on cardboard, should be assembled together on some kind of a light framework attached to one of the walls of the Control Station.

There are a number of reasons which render obligatory the use of these large scale maps for mosquito control work. For one thing, it is only upon maps of this scale that the various ponds, lakes, marshes and other permanent water-places of the district are shown with sufficient completeness; while the majority of the ditches (namely, those which lie along the boundaries of fields, roads, etc.) are also, of course, represented. Ditches and other water-places not shown on the maps must be drawn in as the work proceeds.

Another feature of the 1/2500 scale maps which makes them indispensable for this kind of work is the fact that reference numbers are attached to each field or other enclosed space delineated; and these reference numbers may be made use of for the purpose of "indexing" the various water-places concerned. For example, any ditch which separates two fields is specified by combining the reference numbers of the said fields: a ditch between a field and a road, by the reference number of the field followed by the letter "r" and water-places lying within any area, by the number of the area with suffixed letters. Experience has shown that the locating of the water-places on the map is greatly facilitated by dividing the controlled area into a number of separate sections, each denoted by a different capital letter.

Fig. 37. Mosquito "incubator" containing larval, pupal and adult mosquitoes. Note raisins on netted lid.

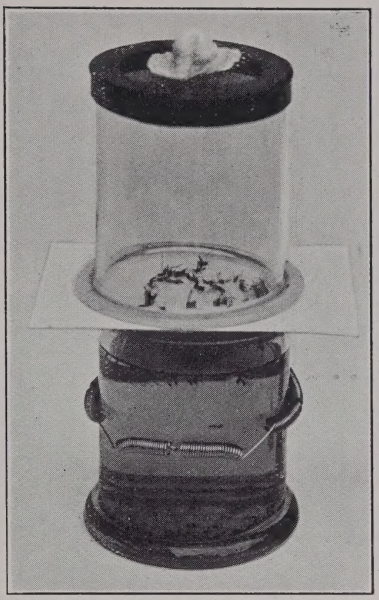

Fig. 38. Adult mosquitoes killed by placing chloroform-soaked wool on netted lid.

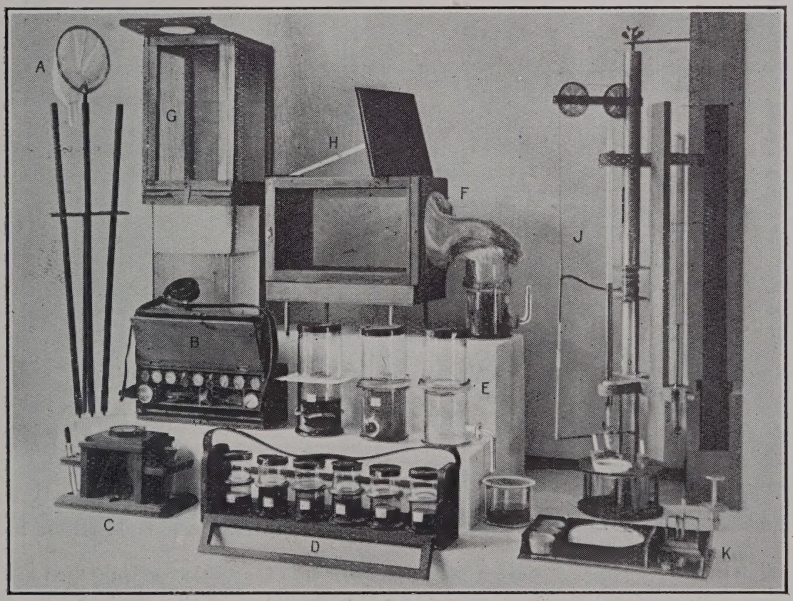

Fig. 39. Special apparatus used in mosquito control work.

A, pond life net with screwed extension rods: B, carrying case containing apparatus for collecting mosquitoes and their larvae: C, dish with reflector below, used for sorting larvae: D, mosquito incubators in carrying frame: E, mosquito incubators: F, mosquito cage connected with incubator: G, mosquito cage attached to tank containing larvae: H, sliding partition for mosquito cage: J, titration apparatus for determining salinity or water: K, apparatus used for mounting adult mosquitoes.

Facing p. 28

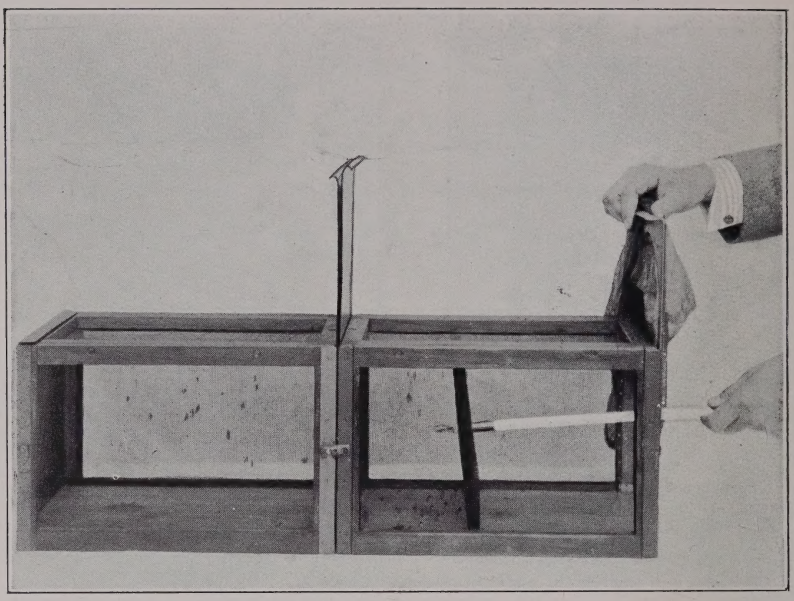

Fig. 40. A batch of adult mosquitoes being driven from one cage into another by means of a sliding partition.

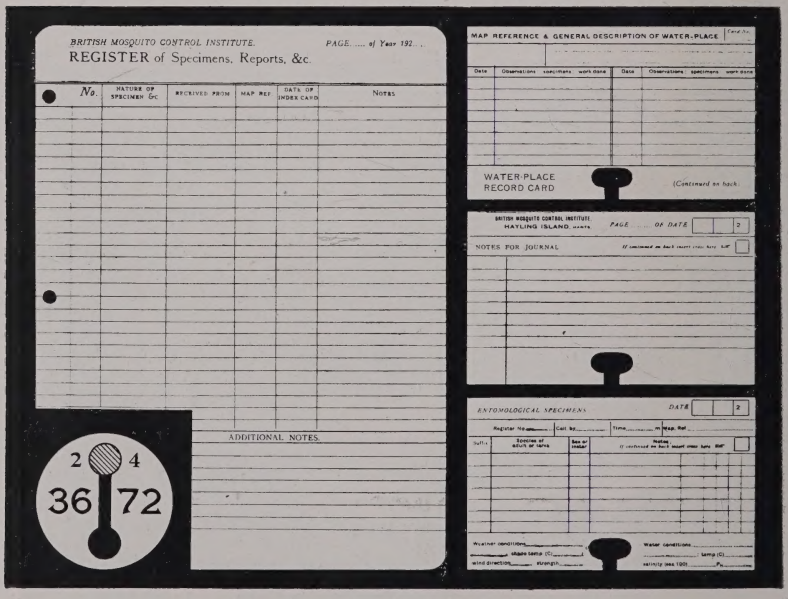

Fig. 41. Register of Specimens, Index Cards and *(inset, actual size)* slotted Indicator Disc as used in the British Mosquito Control Institute.

On the disc shown, the upper figures indicate the year and the lower figures (which are stamped with an automatic numbering machine) the serial reference number of a batch of larvae. The small shaded circle represents the head of a pin inserted in the wall map to show where the larvae were collected.

Facing p. 29

Thus, on the portion of map shown below, the ditch (*) separating field No. 93 from field No. 91 (both fields being located in section "L") would be indexed as "L 93/91"; the ditch (**) between field 93 and the road, as "L 93/r"; the pond *p*, as "L 93/p," and so on.

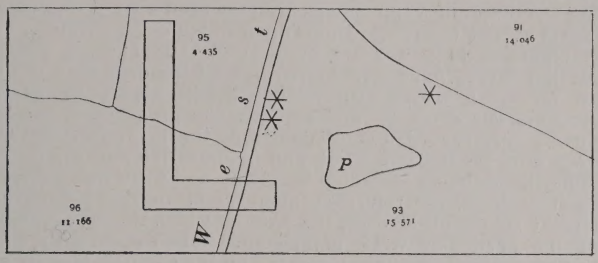

Fig. 42.

To describe the method by which the progress of the work is actually recorded, let it be assumed that a number of water-places have been searched with a pond life net (Figs. 27, 28) and each "catch" of larvae (and the accompanying water) transferred to a storage bottle or tube. Cylindrical tubes about 4 inches long and 1 inch in diameter, with corks, are perhaps the most suitable for this purpose.

Bottles or tubes containing larvae are most effectively "labelled" by interposing, *between the cork and the tube*, a strip of thin cardboard (about $\frac{1}{4}$ inch wide and 3 inches long) extending both above and below the cork; particulars relating to the specimen (*e.g.* date and place of collection, collector's name, reference number, &c.) being written on the upper portion of the strip. In addition to acting as a **label,** the cardboard strip also ensures the **air supply** required by the larvae: while the lower end of the strip, if bent at a right angle, forms a convenient **resting place** for any adult mosquitoes which may hatch out in the tube.

On arrival at the Control Station, each storage tube is given a consecutive reference number, and particulars as to the date and place of collection, as well as the name or initials of the collector, are entered in the **loose-leaf register,** illustrated in Fig. 41. The date of collection and the reference number of each batch of larvae are also entered on the appropriate card in the **water-place index,** each card of which provides a chronological record of all the observations made, the specimens collected and the work carried out in connection with the particular water-place concerned.

After each batch of larvae has been examined, particulars of the species found and of any other facts which are to be recorded are entered on a card of the **specimen index** bearing the reference number of the batch in question.

In certain cases moreover, special circumstances relating to the collection, etc. of some particular batch of specimens have to be recorded on a card of the **journal index,** in which the daily progress of the control work is summarized.

It will be seen, therefore, that the particulars of each batch of specimens received at the Control Station are entered in (i) the **register,** (ii) the **water-place index,** and (iii) the **specimen index:** additional information being occasionally recorded in (iv) the **journal index** also.

Valuable as these records are from the scientific standpoint, they are of only passing interest to the mosquito controller, whose primary duty is to "demobilize" the ascertained breeding areas in the shortest time possible.

Each batch of larvae received at the Control Station directs attention to a particular breeding-place which must be dealt with in some way before the development of adult mosquitoes can take place. It is obvious

that the time available in each case depends upon the stage of development of the larvae found ; breeding places in which *pupae* have appeared must, of course, receive immediate treatment.

In the scheme which has been evolved at Hayling Island the results of examining the different water-places are indicated upon a wall map of the largest scale by the insertion of pins upon which small cardboard discs of various colours and designs are hung (Fig. 41). Thus, a **yellow** disc indicates that *larvae have been collected*, a **white** disc that *the water is free from larvae,* a **white** disc **with a black diametral stripe** that *the water-place has dried up* and so on. The progress of the "control operations" is also recorded continuously on the map, *draining and other engineering work* on the one hand, and *treatment by paraffin or larvicides* on the other hand, being indicated by **green** and **pink** discs respectively. On the yellow discs, the reference numbers of the specimens collected are stamped : on the other discs, the date on which the observations were made or the particular work completed. When occasion requires, the species of larvae collected are indicated on the Control Map by notching the corresponding yellow disc at specified points of its circumference.

A **red** disc is attached to any water-place *which requires immediate attention.*

5. *General Conclusions.*

The foregoing pages of this Section have dealt exclusively with the **scientific** side of mosquito control work—which, as will be noted, involves the co-operation of the entomologist, the chemist and the engineer. There is, however, another side of the question which is perhaps of even greater importance to the mosquito-controller—namely the **financial** one. It is one thing to devise methods for "controlling" mosquitoes, but quite another thing to put them into practical use. In many places abroad, the owner of any property upon which mosquito breeding places are located is compelled by law to contribute the whole, or part, of the cost of their abolition.

In this country, however, although a section of our Public Health Act* is directly applicable to the offence of mosquito breeding, local authorities have hitherto fought shy of taking action in cases of this kind.

Until it becomes generally realised, not only that the owner of a breeding area from which millions of mosquitoes are being "broadcasted" is creating a very serious nuisance over an extensive area, but also that he can, and should, be compelled to abate the nuisance at his own expense, it is obvious that the task of controlling British mosquitoes will continue to be one of considerable difficulty. As things are at present, we have not only to obtain a landowner's leave to drain away his mosquito-infested waters, but also to raise the funds for carrying out the work.

In spite of the fact that the prevalence of mosquitoes in a district is in the highest degree detrimental to all classes of the community, the obvious impossibility of showing immediate benefit from the work undertaken makes it extremely difficult to obtain the necessary support—financial and otherwise—during the first year or two of the campaign. There will always be a certain section of the public who will refuse to assist the work in any circumstances—first maintaining that the task is hopeless, and later on (when the mosquitoes are under control) that it is unnecessary !

Experience has shown, however, that if the work can be kept going sufficiently long, the beneficial results become more and more recognised, with the result that funds and voluntary assistance of various kinds become less difficult to obtain. The mosquito-controller should lose no opportunity of pointing out that complete success can be achieved only through the whole-hearted support of the inhabitants. It is clearly the duty of the householder to render "mosquito proof" the water butts, and ditches on

* See Appendix D, page 37.

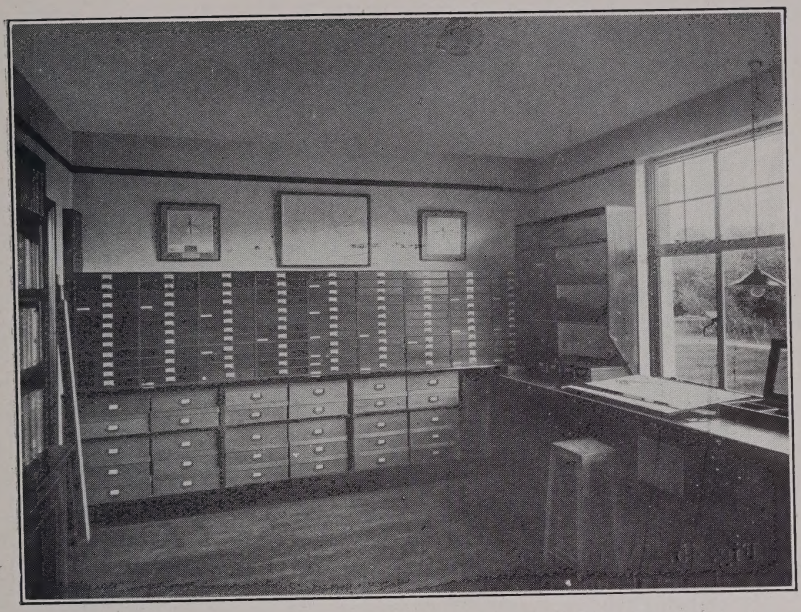

Fig. 43. The Drawing and Record Office.

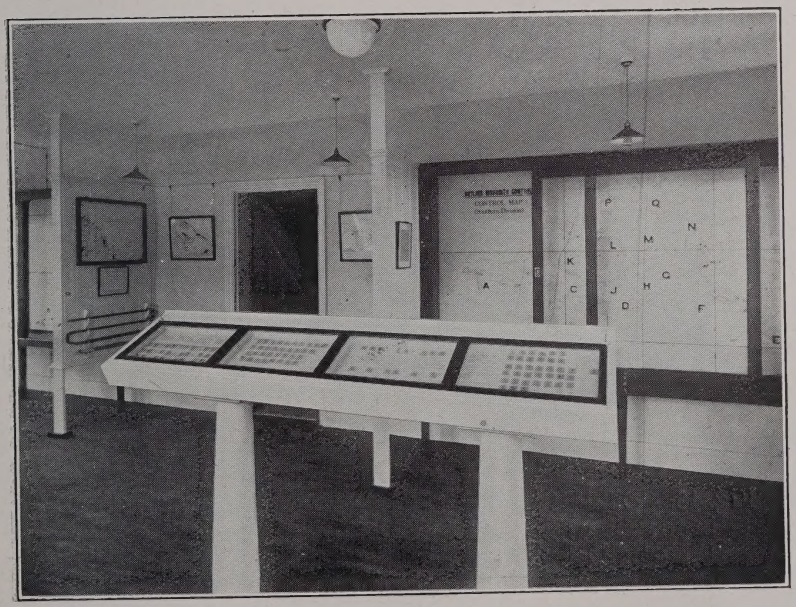

Fig. 44. Indicator Map and Specimen Cases in the Demonstration Museum.

Facing p. 30

Fig. 45.—Methods of examining water for mosquito larvae being demonstrated to School Mosquito Class (Hayling Island).

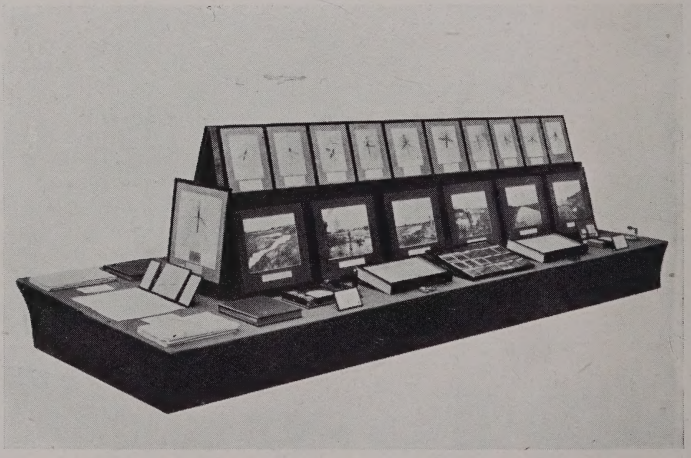

Fig. 46. Exhibit arranged by the Hayling Mosquito Control in the rooms of the Linnean Society, Burlington House, London, Oct. 23rd, 1924.

Facing p. 31

his property †: of the landowner, to see that his farm buildings and fields are properly drained : and of the local authorities, to maintain the roadside ditches and other main channels in proper working order.

If the burden of the work can be to some extent shared in this way, the mosquito staff proper is enabled to devote the greatest time possible to the supervision of those water-places which, owing to large extent, inaccessibility or other reasons, require special and constant supervision.

During the six years which have elapsed since the Hayling Mosquito Control first came into being, a great deal of valuable help has been received from both residents and visitors, particularly as regards the communication of information concerning the presence of larvae in different water-places. The headmaster of the local school has also rendered great assistance by organizing, every year, a "Mosquito Control Class" of schoolchildren. These children, after being instructed in the elements of mosquito control work, are provided with the necessary apparatus for collecting and identifying adult mosquitoes and their larvae. (Fig. 45).

The successful work thus carried on locally has aroused interest in the subject in many other parts of the country, particularly where the inhabitants have suffered from the mosquito nuisance. Many requests have been received for information upon mosquitoes and means of controlling their prevalence, and the Director has given addresses upon the subject before a number of scientific and other bodies, as for example, the Zoology Section of the British Association (Southampton Meeting, 1925),the Sanitary Inspectors' Association (Ramsgate Conference, 1926), the Bournemouth Natural Science Society, the Portsmouth Literary and Philosophical Society, the Wellington College Natural History Society, the Littlehampton Nature and Archæology Circle, and the Research Defence Society (Portsmouth Branch) ; in addition to delivering public lectures at Hayling Island, on a number of occasions, as well as in the Port Library (H.M. Dockyard, Portsmouth) and at Alverstoke, Lavant and other towns.

On October 22nd (1924) an exhibit illustrating the work of the Hayling Mosquito Control was arranged by invitation in the rooms of the Linnean Society of London at Burlington House, London, on the occasion of a reception given by the President and Council of that Society. (Fig. 46).

At the invitation of Colonel S. P. James, M.D., D.P.H. (Adviser on Tropical Diseases to the Ministry of Health), a set of enlarged photographs illustrating the control work at Hayling was included among the exhibits arranged by the Ministry of Health, in H.M. Government Pavilion, at the British Empire Exhibition (Wembley), 1925.

An educational exhibit of photographs and lantern slides, prepared in the Institute to illustrate various branches of mosquito control work, was shown (by invitation of Mr. Oswald Latter, M.A., F.E.S.) at the Annual Meeting of the Science Masters' Association, held at King's College for Women, Campden Hill, London, on January 5th, 6th and 7th, 1926.

The increased accommodation provided by the new Institute building has made it possible to extend greatly the educational aspects of the work, and a large number of demonstrations (both of laboratory and field work) have already been given to parties of students coming from technical colleges and other scientific training centres in Hampshire and Sussex.

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† The control of the "domestic" species, *Culex pipiens* and *Theobaldia annulata*, the female adults of which "hibernate" in the cellars, attics, etc., of dwelling houses, is obviously impossible to carry out without the close co-operation of householders themselves. Every householder (especially if his house is centrally heated) should examine his cellars and attics in October or November, and destroy (by fumigation or spraying) any hibernating mosquitoes found. (See Fig. 8, note).

The latest information relating to the destruction of "domestic" and other mosquitoes may always be obtained from the Institute. New or improved metnods are constantly being introduced, and it was therefore deemed inadvisable to specify any particular larvicides, sprays, fumigants, etc. in the text of the present Handbook.

6. *A Mosquito-Control Summary.*

A mosquito is a two-winged insect (*Fig.* 1), easily recognised by its prominent "proboscis" (*Fig.*2), which the female (but not the male) employs for bloodsucking purposes; and also by the presence of scales on the veins and margins of the wings (*Figs.* 50-53). There are 25 different species of mosquitoes in Great Britain, 3 of these belonging to the ANOPHELINE Tribe and 22 to the CULICINE Tribe. (*pp.* 34-35). Male mosquitoes are easily distinguished from female ones by their long and tufted "palps" and their bushy "antennae" (*Fig.* 3). In the case of female mosquitoes, both the palps and the antennae are smooth and "threadlike": the palps of Anophelines being long, and those of Culicines very short (*Page* 1: *Figs.* 7, 8, 9, *etc.*). The egg-laying methods of different species vary greatly. Some species lay their eggs on water in conglomerate masses called "rafts" (*Fig.* 5): others lay them on water separately: and others lay them in dried-up ditches, depressions and low-lying areas which are likely to collect water during the winter months. When a mosquito egg has been covered with water for a sufficient period (which may be as short as five hours) a **larva** makes its appearance—cutting its way out of the shell by means of a sharp projection attached to its head.

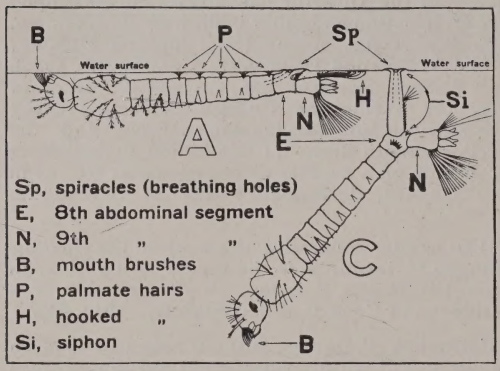

Fig. 47. Anopheline larva (A) and Culicine larva (C).

The larvae of the two mosquito "tribes" are easily distinguished from one another by the fact that the two breathing orifices or "spiracles" of Anopheline larvae are situated directly upon the eighth abdominal segment, whereas those of the Culicine larvae are at the extremity of a tail-like tube (projecting from the eighth segment) called the "siphon". (*Figs.* 4, 11 & 47). The Anopheline larva therefore *lies horizontally*, and the Culicine larva *hangs head downwards*, when breathing—the spiracles, in each case, being brought into the plane of the water surface (*Fig.* 47). Mosquito larvae are provided with a pair of curious "mouth brushes" (*Fig.* 11) by the rapid movement of which various floating particles of food (*p.* 2) are attracted. The Culicine larva obtains its food at various depths, but the Anopheline larva feeds almost exclusively at the surface, being able to twist its head "hind side before" for the purpose, as shown in Fig. 47. The larva changes its skin four times and then becomes a **pupa** (*Fig.* 4), out of which the adult mosquito soon emerges (*Fig.* 6).

British Mosquitoes comprise (1) Domestic Mosquitoes (*p.* 5), which "hibernate" in houses; (2) Rural Mosquitoes, which are subdivided into various groups; and (3) Salt Marsh Mosquitoes (*Fig.* 13, *note*), which have an exceptionally long radius of flight and therefore cause serious annoyance in many seaside resorts. The "control" of mosquitoes involves the oiling, "larviciding" or abolition of the stagnant water in which larvae develop, (*pp.* 24-27) as well as (in the winter only) the destruction of adult mosquitoes during "hibernation" (*Fig.* 8, *note*). The life histories, habits, etc., of different species of mosquitoes are very diverse (*p.*4), and the remedial measures vary accordingly. Enquiries as to methods of control should therefore be accompanied, whenever possible, by specimens of the mosquitoes supposed to be causing annoyance (*pp.* 5, 6). Specimens of larvae, if found, should also be forwarded for identification. (*pp.* 6, 24 & 38).

LEFT EYE. RIGHT EYE.

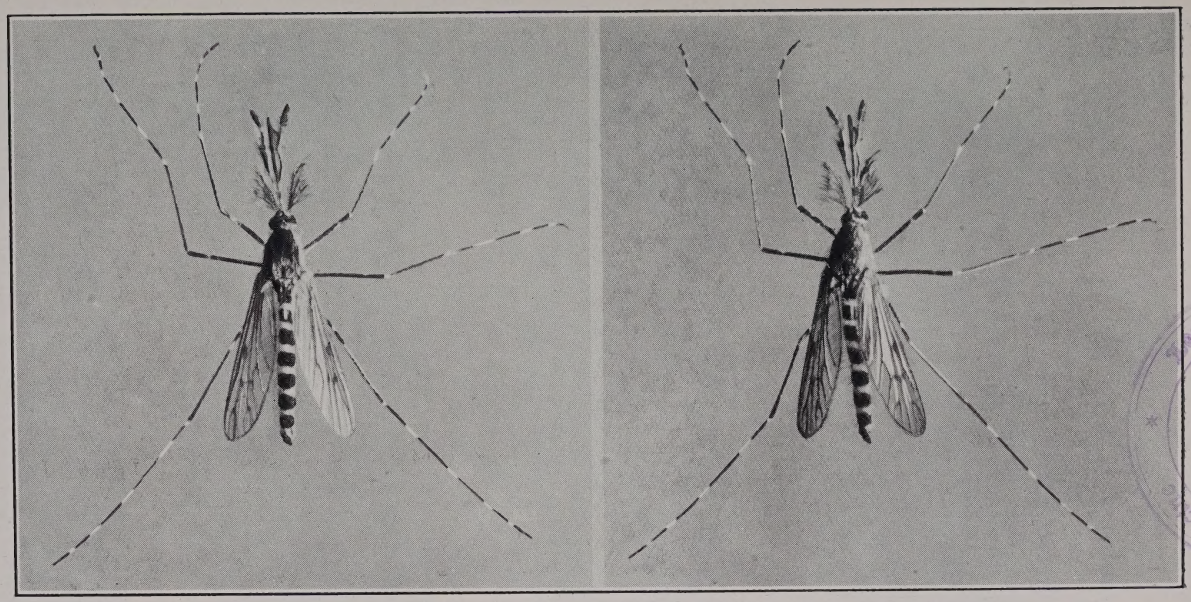

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Fig. 48. Male of the **Culicine** mosquito
Theobaldia annulata.
About $3\frac{1}{2}$ times natural size.

The above illustration reproduces one of the **stereoscopic** photographs of mosquitoes referred to on page 19. If such a photograph is viewed through a stereoscope, the relative positions of the proboscis, palps and antennae are very clearly shown. In this particular case, for example, it will be noted that the extremities of the palps are upwardly inclined.

Facing p. 32

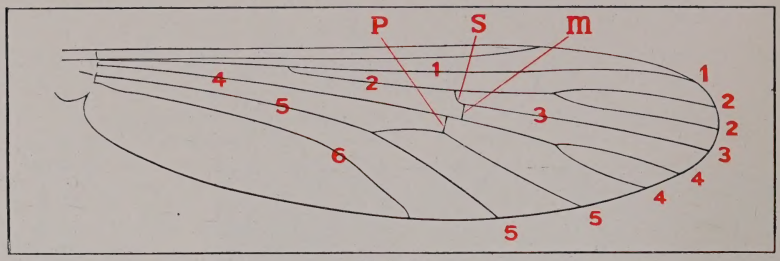

Fig. 49.

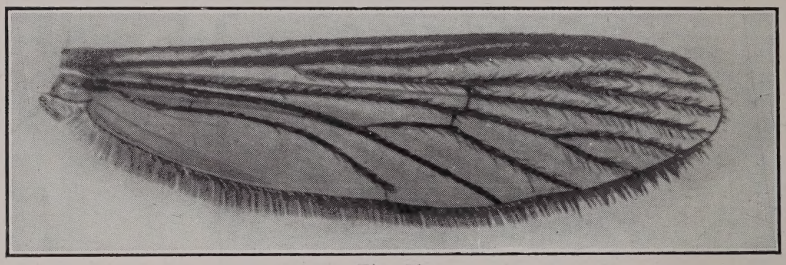

Fig. 50.

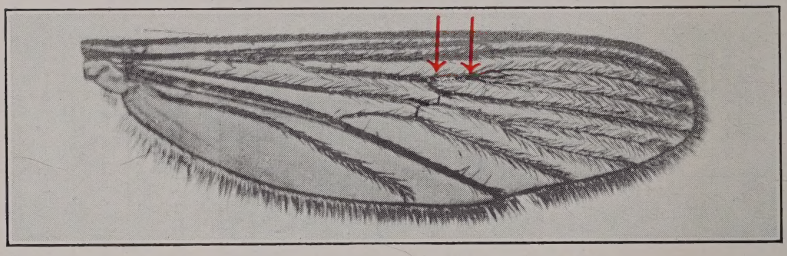

Fig. 51.

Fig. 52.

Fig. 53

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APPENDIX A.

WING VENATION OF MOSQUITOES.

Fig. 49. Wing-venation diagram of a Mosquito.

Note that the 2nd, 4th and 5th longitudinal veins bifurcate before reaching the wing margin. The connecting veins *p*, *m*, *s* are known as the *posterior*, *mid* and *supernumerary cross-veins* respectively. In all English mosquitoes, except *Theobaldia annulata*, the posterior cross-vein lies on the "inside" of the mid cross-vein, as shown in the diagram.

Fig. 50. Wing of female *Aedes rusticus.*

Note the scales on the wing veins and also the fringe of scales along wing margin—characteristic features of all mosquitoes.

Fig. 51. Wing of female *Culex pipiens.*

Note that, *in this English species only*, the portion of the 2nd longitudinal vein lying *between the supernumerary cross-vein and the point of bifurcation* (i.e., the portion of the vein between the arrow points) is *exceptionally short:* the "*forked*" *portion* of the vein being in consequence *exceptionally long*. This abnormality enables *Culex pipiens* to be distinguished very easily from all other English mosquitoes.

Fig. 52. Wing of female *Theobaldia annulata.*

Theobaldia annulata and *Anopheles maculipennis* are the only English mosquitoes which have "spotted" wings, these spots being due to an *overcrowding* of scales at certain vein junctions. Note that the "*p*" and "*m*" veins of *Theobaldia* (but *not* those of *Anopheles maculipennis*) are in line with one another.

Fig. 53. Wing of female *Rhyphus fenestralis.*

Rhyphus fenestralis is not a mosquito, but is one of many two-winged insects which (in spite of having no proboscis) is frequently mistaken for one. The object of this photograph is to show that in the case of any two-winged insect *other than a mosquito*:—

(a) The wing veins form *some different pattern* to those of a mosquito.

(b) The wing veins and the wing margin are *devoid of scales.*

(c) The wing "spots," when present, are not *scale clusters* (as in mosquitoes) but *pigmented patches.*

Classification of the British Mosquitoes. (i)

The figures in brackets and marginal letters refer to notes on opposite page.

I. ANOPHELINE Tribe (ii)

GENUS Anopheles.

1	*Anopheles maculipennis*, Meigen. (iv)	(i) DSU
2	*Anopheles bifurcatus*, Linnaeus. (v)	U
3	*Anopheles plumbeus*, Stephens. (v)	LTU

II. CULICINE Tribe (ii)

GENUS Aedes.

(Pair of hair tufts at, or near, centre of larval siphon). (iii)

4	*Aedes [Ochlerotatus]* caspius*, Pallas. (vi)	CLR
5	*Aedes do. dorsalis*, Meigen	R
6	*Aedes do. lutescens*, Fabricius. (vii)	RU
7	*Aedes do. annulipes*, Meigen	R
8	*Aedes do. maculatus*, Meigen. (viii)	RW
9	*Aedes do. rusticus*, Rossi. (ix)	LW
10	*Aedes do. communis*, De Geer	W
11	*Aedes do. salinellus*, Edwards	C
12	*Aedes do. detritus*, Haliday. (iv)	C
13	*Aedes do. punctor*, Kirby. (x)	LW
14	*Aedes do. sticticus*, Meigen	
15	*Aedes [Finlaya] geniculatus*, Olivier	KLTU
16	*Aedes [Aedimorphus] vexans*, Meigen	R
17	*Aedes [Aedes] cinereus*, Meigen. (xi)	U

GENUS Theobaldia.

(Pair of hair tufts near base of larval siphon).

18	*Theobaldia [Theobaldia] annulata*, Schrank. (iv)	DMRS
18A	*Theobaldia do. ,, var: subochrea*, Edw. (xii)	
19	*Theobaldia do. alaskaensis*, Ludlow	RS
20	*Theobaldia [Culicella] morsitans*, Theobald	R
21	*Theobaldia do. fumipennis*, Stephens	R

GENUS Orthopodomyia.

(No pecten on larval siphon).

22	*Orthopodomyia pulchripalpis*, Rondani	LRT

GENUS Taeniorhynchus.

(Larval siphon adapted for piercing stems of submerged plants).

23	*Taeniorhynchus richiardii*, Ficalbi	RU

GENUS Culex.

(Four pairs of hair tufts on larval siphon).

24	*Culex [Culex] pipiens*, Linnaeus. (iv)	DM
25	*Culex do. apicalis*, Adams	

* [Sub-generic names in square brackets.]

(i). Mosquitoes are to be met with all over the world, the total number of species at present known exceeding 1400. With a few unimportant exceptions they are separable into two great divisions or "tribes" the *ANOPHELINES* and the *CULICINES*, something like three-quarters of the mosquitoes of the world belonging to the latter tribe. In Great Britain, 3 species of *ANOPHELINE*, and 22 species of *CULICINE*, mosquitoes have up to now been discovered.

Of the British mosquitoes enumerated on the opposite page, the **abdomens** of the 3 *ANOPHELINES* and of four only of the *CULICINES* are **unicoloured** (U), whereas those of the remaining species are conspicuously marked by white or yellowish **transverse bands.** Among the characteristic features of different mosquitoes are **ringed legs** (R), **"spotted" wings** (S), **white knee-joints** (K) and **light or dark thoracic lines or stripes** (L). Some mosquitoes breed chiefly in or near **woods** (W), others in rain-filled **tree-holes** (T) and others generally or exclusively in **coastal** districts (C), Three British species are called **"domestic"** mosquitoes (D), because the female adults "hibernate" in cellars, stables, etc. : two of these species lay their eggs in conglomerate **masses** called "rafts." (M).

(ii). Female mosquitoes of the two tribes are readily distinguished from one another by the length of the **palps,** which are about *the same length as the proboscis* in *ANOPHELINES*, and about *one-fifth of its length* in *CULICINES*. (*See page 1 & Figs. 1, 7 & 8*). The tribe to which a **larva** belongs is equally easily recognised by its resting position below the water surface—the *ANOPHELINE* larva (which breathes through two holes near its hinder end) lying *horizontally*, and the *CULICINE* larva (which breathes through a tail-like tube called the "siphon") hanging *head downwards*. (*See Fig. 47*).

(iii). The siphon of a Culicine larva carries, *on each side*, a tufted hair (in some cases more than one), the position of which indicates the *genus*, while variations in other appendages indicate the *species*. (*See Fig. 11*).

(iv). For illustrated descriptions of the mosquitoes *Anopheles maculipennis, Culex pipiens, Theobaldia annulata and Aedes detritus* see *Figs. 7, 8, 9,* and *13* respectively.

(v). See notes appended to *Figure 7, facing page 3.*

(vi). *Aedes caspius* is easily recognised. The thorax is yellow, with two longitudinal white stripes. The legs are conspicuously ringed. The abdomen is brown with white transverse bands and also a *continuous median white stripe*. This species breeds chiefly in brackish water near the coast, but also (unlike *A. detritus*) occasionally in inland waters.

(vii). *Aedes lutescens*, a handsome mosquito with a uniformly yellow abdomen, was first found in England by Mr. P. G. Shute, at Queenborough (Kent) in *1922*.

(viii). *Aedes maculatus* is a rather dark mosquito, with ringed legs, which breeds chiefly in temporary pools in woods, where it often causes serious annoyance.

(ix). *Aedes rusticus* is nearly as large a mosquito as *Theobaldia annulata*, but the two species are very easily differentiated, since *Aedes rusticus* has unspotted wings and unicoloured legs. The thorax is brown with five dark stripes. The abdomen is brown with yellowish bands and a more or less continuous median stripe. The larvae are found chiefly in pools containing dead leaves. (*See Fig. 12*).

(x). *Aedes punctor* (like *A. maculatus*) breeds in temporary woodland pools, but is more or less confined to districts in which coniferous trees predominate. The thorax is brown, with one broad dark stripe.

(xi). In males of the species *Aedes cinereus*, the antennae are *bushy* (like those of all male mosquitoes) but the palps are *short*, like those of a Culicine **female**. *Aedes cinereus* is the only British mosquito which exhibits this peculiarity.

(xii). A brownish "variety" of *Theobaldia annulata.*

APPENDIX C.

FORMULAE RELATING TO "OILING" AND "LARVICIDING."

It is common knowledge that, under favourable conditions, a small quantity of oil, such as paraffin, will diffuse over the surface of water so as to cover a very large area with a film of almost unbelievable tenuity. In mosquito control work, however, the oil film must be sufficiently thick to ensure that a perceptible "dose" of paraffin enters the breathing apparatus of each larva when it comes to the surface. Experiments made in Hayling in 1921 showed that, for practical purposes, one pint of paraffin should be distributed over each 40 square yards of surface: the thickness of the film being therefore 1/1500 of an inch.

Owing to the difficulty of maintaining a sufficiently lasting oil film in wind-swept areas, it is generally advisable to make use of **larvicides** when *coastal* mosquitoes (*Aedes detritus*, *Aedes caspius*) are concerned.

In dealing with sheltered breeding-places, the question of which method shall be adopted is largely one of expense. It must be remembered that when **paraffin** is used, the amount required depends only upon the **area of surface** to be treated: but in the case of a **larvicide,** which has to diffuse throughout the whole body of water, the **depth of the water** is also an important factor. If the thickness of an effective paraffin film is assumed to be 1/1500 inch, then the cost of treating a piece of water of depth d inches with a larvicide which is c times as expensive as paraffin, and which has to be mixed with the infested water in a strength of 1 in n is

$$\frac{1500 \times c \times d}{n}$$

times the cost of paraffining the same piece of water.*

In the case of any larvicide for which c and n are known, it is easy to calculate the depth of water at which the cost of paraffining and larviciding are the same.

Since a cubic yard is the space occupied by 168 gallons, it follows that the number of gallons in any piece of water is

$$\frac{14}{3} \times A \times d$$

where A is the surface area in square yards
and d is the depth in inches.

So that, if any larvicide is to be used in the proportion of 1 in n, the number of gallons required will be

$$\frac{14}{3} \times \frac{A \times d}{n} \text{ gallons}$$

a useful formula for calculation, particularly when a definite value of "n" has been decided upon for treating a number of ponds. Suppose, for instance, that a larvicide is to be used in a proportion of 1 in 14,000, then the amount required will be

$$\frac{A \times d}{3000} \text{ gallons,}$$

while a 1 in 28,000 proportion would require

$$\frac{A \times d}{6000} \text{ gallons,}$$

and so on.

---

* This formula first appeared in an article written by the author for the scientific quarterly, *Science Progress* (January, 1922).

APPENDIX D.

MOSQUITOES AND THE PUBLIC HEALTH ACTS.

Among the "nuisances" defined by the Public Health Act, 1875 (§ 91) and the Public Health (Scotland) Act, 1897 (§ 16) are included *any pool, ditch, gutter, watercourse, sink, cistern, cesspool or drain so foul or in such a state or so situated as to be a nuisance or injurious or dangerous to health.*

The succeeding Section in each of the above Acts states that it shall be the duty of every local authority to cause to be made from time to time inspection of their district, with a view to ascertain what nuisances exist calling for abatement under the powers of the Act, and to enforce the provisions of the Act in order to abate the same.

Although the provisions of the Sections referred to appear to be peculiarly applicable to the offence of breeding mosquitoes, local authorities have hitherto fought shy of taking action in cases of this nature. The result is that schemes for controlling mosquitoes in Great Britain are, generally speaking, hampered by lack of financial support: the average citizen being naturally averse to subscribing funds for the purpose of draining the nuisance-producing land of one or more of his neighbours. It is not, therefore, surprising that the local authorities of many British "resorts" continue to tolerate mosquitoes (apparently relying upon an influx of "first-time" visitors in each season) in preference to attacking them under the unfavourable conditions at present prevailing.

An action taken, however, early in 1927 by the Upper District Committee of the County of Renfrew against the proprietor of certain ditches on lands at Muirend in which a public nuisance caused by the presence of mosquitoes was alleged, affords a precedent which, it may be hoped, will be followed by other local authorities. The judgment of Sheriff Hamilton in Paisley Sheriff Court, on June 14th, 1927, in this case was that the ditches in question were a public nuisance as described under the Public Health (Scotland) Act, and the defendant was ordered to have them cleansed.

The ditches were in close proximity to a residential district in the outskirts of the City of Glasgow, and it was shown that they had become a breeding place for large quantities of mosquitoes which invaded the district and attacked the residents. His Lordship held "that the bites of the said mosquitoes caused pain and swelling, occasioning in some cases temporary incapacity, and followed in some cases by septic sores, and that their presence caused reasonable apprehension and diminution of comfort in the community."

The defendant was therefore ordered to clear the ditches of the silt and vegetable growth, and thus to remove the nuisance from mosquitoes to which such conditions gave rise.

It need scarcely be said that the result of this case is of the highest importance and will be of the greatest assistance to all who are concerned with either the principles or the practice of mosquito control.

Regulations concerning the TRANSMISSION OF GLASS, LIQUIDS, &c., BY POST.

CROCKERY,	LIQUIDS,
GLASS,	SEMI-LIQUIDS,
GREASE	COLOURING POWDERS

should be sent by **Parcel Post.**

They may, however be sent by Letter Post under the following conditions: —

1. Nothing inflammable, corrosive, or explosive may be sent, nor anything having an odour so strong as to affect the contents of other packets in the Mails.

2. No article liable to Customs duty may be sent by letter Post to or from the Channel Islands or the Isle of Man.

3. They must be packed as follows :—

Glass and Crockery must be securely packed (in boxes of metal, wood, leather, or cardboard) in such a way as to prevent all risks of injury to the Mails or Officers of the Post Office.

Liquids must be enclosed in bottles firmly sealed; the bottles must be enclosed in a box of wood, leather, metal or strong corrugated cardboard, and packed securely in the box by means of corrugated paper or other suitable material a sufficient quantity of sawdust or some spongy substance being added to absorb all the liquid contents in case of the bottle being broken. Special attention must be be paid to the packing round the shoulders of the bottle; and the box must open at one end only, and have a tightly fitting lid or a screw lid.

Semi-Liquids and Greases must have an inner covering securely closed, and an outer covering of metal, wood or leather, sufficiently strong to prevent any risk of the contents escaping during transit.

Powders must have an inner covering securely closed, and a strong outer covering of metal, wood, leather, or cardboard.

4. They are sent **at the Sender's Risk,** the Postmaster-General accepting no liability in the case of either loss or damage, even if the packets are registered.

5. If insecurely packed they will be stopped. The Public are warned that such insecurely packed packets come within the category of articles "likely to injure other postal packets in course of conveyance or an Officer of the Post Office," and are, therefore, prohibited from being sent by post. The senders of such packets are liable to penalties under the Post Office Act, 1908, whether the packets are sent by Letter or Parcel Post.

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